INTRODUCTION

1. Overview

The *Review of Particle Physics* and the abbreviated version, the *Particle Physics Booklet,* are reviews of the field of Particle Physics. This complete *Review* includes a compilation/evaluation of data on particle properties, called the "Particle Listings." These Listings include 1726 new measurements from 512 papers, in addition to the 20,200 measurements from 5903 papers that first appeared in previous editions.

Both books include Summary Tables with our best values and limits for particle properties such as masses, widths or lifetimes, and branching fractions, as well as an extensive summary of searches for hypothetical particles. In addition, we give a long section of "Reviews, Tables, and Plots" on a wide variety of theoretical and experimental topics, a quick reference for the practicing particle physicist.

The *Review* and the *Booklet* are published in even-numbered years. This edition is an updating through December 2003 (and, in some areas, well into 2004). As described in the section "Using Particle Physics Databases" following this introduction, the content of this *Review* is available on the World-Wide Web, and is updated between printed editions (`http://pdg.lbl.gov/`).

The Summary Tables give our best values of the properties of the particles we consider to be well established, a summary of search limits for hypothetical particles, and a summary of experimental tests of conservation laws.

The Particle Listings contain all the data used to get the values given in the Summary Tables. Other measurements considered recent enough or important enough to mention, but which for one reason or another are not used to get the best values, appear separately just beneath the data we do use for the Summary Tables. The Particle Listings also give information on unconfirmed particles and on particle searches, as well as short "reviews" on subjects of particular interest or controversy.

The Particle Listings were once an archive of all published data on particle properties. This is no longer possible because of the large quantity of data. We refer interested readers to earlier editions for data now considered to be obsolete.

We organize the particles into six categories:

- Gauge and Higgs bosons
- Leptons
- Quarks
- Mesons
- Baryons
- Searches for monopoles, supersymmetry, compositeness, extra dimensions, *etc.*

The last category only includes searches for particles that do not belong to the previous groups; searches for heavy charged leptons and massive neutrinos, by contrast, are with the leptons.

In Sec. 2 of this Introduction, we list the main areas of responsibility of the authors, and also list our large number of consultants, without whom we would not have been able to produce this *Review.* In Sec. 3, we mention briefly the naming scheme for hadrons. In Sec. 4, we discuss our procedures for choosing among measurements of particle properties and for obtaining best values of the properties from the measurements.

The accuracy and usefulness of this *Review* depend in large part on interaction between its users and the authors. We appreciate comments, criticisms, and suggestions for improvements of any kind. Please send them to the appropriate author, according to the list of responsibilities in Sec. 2 below, or to the LBNL addresses below.

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3. Naming scheme for hadrons

We introduced in the 1986 edition [2] a new naming scheme for the hadrons. Changes from older terminology affected mainly the heavier mesons made of u, d, and s quarks. Otherwise, the only important change to known hadrons was that the $F^{\pm}$ became the $D_s^{\pm}$. None of the lightest pseudoscalar or vector mesons changed names, nor did the $c\overline{c}$ or $b\overline{b}$ mesons (we do, however, now use χ_c for the $c\overline{c}$ χ states), nor did any of the established baryons. The Summary Tables give both the new and old names whenever a change has occurred.

The scheme is described in "Naming Scheme for Hadrons" (p. 102) of this *Review*.

We give here our conventions on type-setting style. Particle symbols are italic (or slanted) characters: e^-, p, Λ, π^0, K_L, D_s^+, b. Charge is indicated by a superscript: B^-, Δ^{++}. Charge is not normally indicated for p, n, or the quarks, and is optional for neutral isosinglets: η or η^0. Antiparticles and particles are distinguished by charge for charged leptons and mesons: τ^+, K^-. Otherwise, distinct antiparticles are indicated by a bar (overline): $\overline{\nu}_\mu$, $\overline{t}$, $\overline{p}$, $\overline{K}^0$, and $\overline{\Sigma}^+$ (the antiparticle of the Σ^-).

4. Procedures

4.1. *Selection and treatment of data*: The Particle Listings contain all relevant data known to us that are published in journals. With very few exceptions, we do not include results from preprints or conference reports. Nor do we include data that are of historical importance only (the Listings are not an archival record). We search every volume of 20 journals through our cutoff date for relevant data. We also include later published papers that are sent to us by the authors (or others).

In the Particle Listings, we clearly separate measurements that are used to calculate or estimate values given in the Summary Tables from measurements that are not used. We give explanatory comments in many such cases. Among the reasons a measurement might be excluded are the following:

- It is superseded by or included in later results.
- No error is given.
- It involves assumptions we question.
- It has a poor signal-to-noise ratio, low statistical significance, or is otherwise of poorer quality than other data available.
- It is clearly inconsistent with other results that appear to be more reliable. Usually we then state the criterion, which sometimes is quite subjective, for selecting "more reliable" data for averaging. See Sec. 4.4.
- It is not independent of other results.
- It is not the best limit (see below).
- It is quoted from a preprint or a conference report.

In some cases, *none* of the measurements is entirely reliable and no average is calculated. For example, the masses of many of the baryon resonances, obtained from partial-wave analyses, are quoted as estimated ranges thought to probably include the true values, rather than as averages with errors. This is discussed in the Baryon Particle Listings.

For upper limits, we normally quote in the Summary Tables the strongest limit. We do not average or combine upper limits except in a very few cases where they may be re-expressed as measured numbers with Gaussian errors.

As is customary, we assume that particle and antiparticle share the same spin, mass, and mean life. The Tests of Conservation Laws table, following the Summary Tables, lists tests of CPT as well as other conservation laws.

We use the following indicators in the Particle Listings to tell how we get values from the tabulated measurements:

- OUR AVERAGE—From a weighted average of selected data.
- OUR FIT—From a constrained or overdetermined multiparameter fit of selected data.
- OUR EVALUATION—Not from a direct measurement, but evaluated from measurements of related quantities.
- OUR ESTIMATE—Based on the observed range of the data. Not from a formal statistical procedure.
- OUR LIMIT—For special cases where the limit is evaluated by us from measured ratios or other data. Not from a direct measurement.

An experimentalist who sees indications of a particle will of course want to know what has been seen in that region in the past. Hence we include in the Particle Listings all reported states that, in our opinion, have sufficient statistical merit and that have not been disproved by more reliable data. However, we promote to the Summary Tables only those states that we feel are well established. This judgment is, of course, somewhat subjective and no precise criteria can be given. For more detailed discussions, see the minireviews in the Particle Listings.

4.2. ***Averages and fits***: We divide this discussion on obtaining averages and errors into three sections: (1) treatment of errors; (2) unconstrained averaging; (3) constrained fits.

4.2.1. *Treatment of errors:* In what follows, the "error" δx means that the range $x \pm \delta x$ is intended to be a 68.3% confidence interval about the central value x. We treat this error as if it were Gaussian. Thus when the error *is* Gaussian, δx is the usual one standard deviation (1σ). Many experimenters now give statistical and systematic errors separately, in which case we usually quote both errors, with the statistical error first. For averages and fits, we then add the the two errors in quadrature and use this combined error for δx.

When experimenters quote asymmetric errors $(\delta x)^+$ and $(\delta x)^-$ for a measurement x, the error that we use for that measurement in making an average or a fit with other measurements is a continuous function of these three quantities. When the resultant average or fit $\overline{x}$ is less than $x-(\delta x)^-$, we use $(\delta x)^-$; when it is greater than $x+(\delta x)^+$, we use $(\delta x)^+$. In between, the error we use is a linear function of x. Since the errors we use are functions of the result, we iterate to get the final result. Asymmetric output errors are determined from the input errors assuming a linear relation between the input and output quantities.

In fitting or averaging, we usually do not include correlations between different measurements, but we try to select data in such a way as to reduce correlations. Correlated errors are, however, treated explicitly when there are a number of results of the form $A_i \pm \sigma_i \pm \Delta$ that have identical systematic errors Δ. In this case, one can first average the $A_i \pm \sigma_i$ and then combine the resulting statistical error with Δ. One obtains, however, the same result by averaging $A_i \pm (\sigma_i^2 + \Delta_i^2)^{1/2}$, where $\Delta_i = \sigma_i \Delta [\sum (1/\sigma_j^2)]^{1/2}$. This procedure has the advantage that, with the modified systematic errors Δ_i, each measurement may be treated as independent and averaged in the usual way with other data. Therefore, when appropriate, we adopt this procedure. We tabulate Δ and invoke an automated procedure that computes Δ_i before averaging and we include a note saying that there are common systematic errors.

Another common case of correlated errors occurs when experimenters measure two quantities and then quote the two and their difference, *e.g.*, m_1, m_2, and $\Delta = m_2 - m_1$. We cannot enter all of m_1, m_2 and Δ into a constrained fit because they are not independent. In some cases, it is a good approximation to ignore the quantity with the largest error and put the other two into the fit. However, in some cases correlations are such that the errors on m_1, m_2 and Δ are comparable and none of the three values can be ignored. In this case, we put all three values into the fit and invoke an automated procedure to increase the errors prior to fitting such that the three quantities can be treated as independent measurements in the constrained fit. We include a note saying that this has been done.

4.2.2. *Unconstrained averaging:* To average data, we use a standard weighted least-squares procedure and in some cases, discussed below, increase the errors with a "scale factor." We begin by assuming that measurements of a given quantity are uncorrelated, and calculate a weighted average and error as

$$\overline{x} \pm \delta\overline{x} = \frac{\sum_i w_i \, x_i}{\sum_i w_i} \pm \left(\sum_i w_i\right)^{-1/2} , \tag{1}$$

where

$$w_i = 1/(\delta x_i)^2 \; .$$

Here x_i and δx_i are the value and error reported by the ith experiment, and the sums run over the N experiments. We then calculate $\chi^2 = \sum w_i(\overline{x} - x_i)^2$ and compare it with $N-1$, which is the expectation value of χ^2 if the measurements are from a Gaussian distribution.

If $\chi^2/(N-1)$ is less than or equal to 1, and there are no known problems with the data, we accept the results.

If $\chi^2/(N-1)$ is very large, we may choose not to use the average at all. Alternatively, we may quote the calculated average, but then make an educated guess of the error, a conservative estimate designed to take into account known problems with the data.

Finally, if $\chi^2/(N-1)$ is greater than 1, but not greatly so, we still average the data, but then also do the following:

(a) We increase our quoted error, $\delta\overline{x}$ in Eq. (1), by a scale factor S defined as

$$S = \left[\chi^2/(N-1)\right]^{1/2} \; . \tag{2}$$

Our reasoning is as follows. The large value of the χ^2 is likely to be due to underestimation of errors in at least one of the experiments. Not knowing which of the errors are underestimated, we assume they are all underestimated by the same factor S. If we scale up all the input errors by this factor, the χ^2 becomes $N-1$, and of course the output error $\delta\overline{x}$ scales up by the same factor. See Ref. 3.

When combining data with widely varying errors, we modify this procedure slightly. We evaluate S using only the experiments with smaller errors. Our cutoff or ceiling on δx_i is arbitrarily chosen to be

$$\delta_0 = 3N^{1/2}\,\delta\overline{x}\ ,$$

where $\delta\overline{x}$ is the unscaled error of the mean of all the experiments. Our reasoning is that although the low-precision experiments have little influence on the values $\overline{x}$ and $\delta\overline{x}$, they can make significant contributions to the χ^2, and the contribution of the high-precision experiments thus tends to be obscured. Note that if each experiment has the same error δx_i, then $\delta\overline{x}$ is $\delta x_i/N^{1/2}$, so each δx_i is well below the cutoff. (More often, however, we simply exclude measurements with relatively large errors from averages and fits: new, precise data chase out old, imprecise data.)

Our scaling procedure has the property that if there are two values with comparable errors separated by much more than their stated errors (with or without a number of other values of lower accuracy), the scaled-up error $\delta\,\overline{x}$ is approximately half the interval between the two discrepant values.

We emphasize that our scaling procedure for *errors* in no way affects central values. And if you wish to recover the unscaled error $\delta\overline{x}$, simply divide the quoted error by S.

(b) If the number M of experiments with an error smaller than δ_0 is at least three, and if $\chi^2/(M-1)$ is greater than 1.25, we show in the Particle Listings an ideogram of the data. Figure 1 is an example. Sometimes one or two data points lie apart from the main body; other times the data split into two or more groups. We extract no numbers from these ideograms; they are simply visual aids, which the reader may use as he or she sees fit.

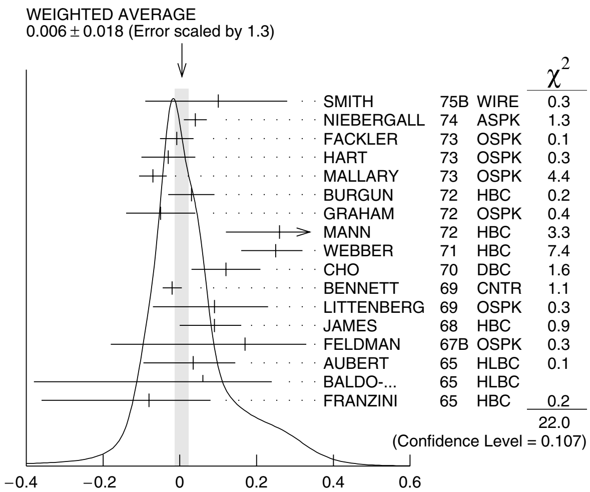

Figure 1: A typical ideogram. The arrow at the top shows the position of the weighted average, while the width of the shaded pattern shows the error in the average after scaling by the factor S. The column on the right gives the χ^2 contribution of each of the experiments. Note that the next-to-last experiment, denoted by the incomplete error flag ($\perp$), is not used in the calculation of S (see the text).

Each measurement in an ideogram is represented by a Gaussian with a central value x_i, error δx_i, and area proportional to $1/\delta x_i$. The choice of $1/\delta x_i$ for the area is somewhat arbitrary. With this choice, the center of gravity of the ideogram corresponds to an average that uses weights $1/\delta x_i$ rather than the $(1/\delta x_i)^2$ actually used in the averages. This may be appropriate when some of the experiments have seriously underestimated systematic errors. However, since for this choice of area the height of the Gaussian for each measurement is proportional to $(1/\delta\,x_i)^2$, the peak position of the ideogram will often favor the high-precision measurements at least as much as does the least-squares average. See our 1986 edition [2] for a detailed discussion of the use of ideograms.

4.2.3. *Constrained fits:* In some cases, such as branching ratios or masses and mass differences, a constrained fit may be needed to obtain the best values of a set of parameters. For example, most branching ratios and rate measurements are analyzed by making a simultaneous least-squares fit to all the data and extracting the partial decay fractions P_i, the partial widths Γ_i, the full width Γ (or mean life), and the associated error matrix.

Assume, for example, that a state has m partial decay fractions P_i, where $\sum P_i = 1$. These have been measured in N_r different ratios R_r, where, e.g., $R_1 = P_1/P_2$, $R_2 = P_1/P_3$, *etc.* [We can handle any ratio R of the form $\sum \alpha_i\,P_i/\sum \beta_i\,P_i$, where α_i and β_i are constants, usually 1 or 0. The forms $R = P_iP_j$ and $R = (P_iP_j)^{1/2}$ are also allowed.] Further assume that *each* ratio R has been measured by N_k experiments (we designate each experiment with a subscript k, e.g., R_{1k}). We then find the best values of the fractions P_i by minimizing the χ^2 as a function of the $m-1$ independent parameters:

$$\chi^2 = \sum_{r=1}^{N_r}\sum_{k=1}^{N_k}\left(\frac{R_{rk}-R_r}{\delta R_{rk}}\right)^2\ , \qquad (3)$$

where the R_{rk} are the measured values and R_r are the fitted values of the branching ratios.

In addition to the fitted values $\overline{P}_i$, we calculate an error matrix $\langle\delta\overline{P}_i\ \delta\overline{P}_j\rangle$. We tabulate the diagonal elements of $\delta\,\overline{P}_i = \langle\delta\,\overline{P}_i\ \delta\,\overline{P}_i\rangle^{1/2}$ (except that some errors are scaled as discussed below). In the Particle Listings, we give the complete correlation matrix; we also calculate the fitted value of each ratio, for comparison with the input data, and list it above the relevant input, along with a simple unconstrained average of the same input.

Three comments on the example above:

(1) There was no connection assumed between measurements of the full width and the branching ratios. But often we also have information on partial widths Γ_i as well as the total width Γ. In this case we must introduce Γ as a parameter in the fit, along with the P_i, and we give correlation matrices for the widths in the Particle Listings.

(2) We try to pick those ratios and widths that are as independent and as close to the original data as possible. When one experiment measures all the branching fractions and constrains their sum to be one, we leave one of them (usually the least well-determined one) out of the fit to make the set of input data more nearly independent. We now do allow for correlations between input data.

(3) We calculate scale factors for both the R_r and P_i when the measurements for any R give a larger-than-expected contribution to the χ^2. According to Eq. (3), the

double sum for χ^2 is first summed over experiments $k = 1$ to N_k, leaving a single sum over ratios $\chi^2 = \sum \chi_r^2$. One is tempted to define a scale factor for the ratio r as $S_r^2 = \chi_r^2/\langle\chi_r^2\rangle$. However, since $\langle\chi_r^2\rangle$ is not a fixed quantity (it is somewhere between N_k and N_{k-1}), we do not know how to evaluate this expression. Instead we define

$$S_r^2 = \frac{1}{N_k}\sum_{k=1}^{N_k}\frac{\left(R_{rk}-\overline{R}_r\right)^2}{\langle(R_{rk}-\overline{R}_r)^2\rangle}. \tag{4}$$

With this definition the expected value of S_r^2 is one. We can show that

$$\langle(R_{rk}-\overline{R}_r)^2\rangle = (\delta R_{rk})^2 - (\delta\overline{R}_r)^2\ , \tag{5}$$

where $\delta\overline{R}_r$ is the fitted error for ratio r.

The fit is redone using errors for the branching ratios that are scaled by the larger of S_r and unity, from which new and often larger errors $\delta\overline{P}_i^{\prime}$ are obtained. The scale factors we finally list in such cases are defined by $S_i = \delta\overline{P}_i^{\prime}/\delta\overline{P}_i$. However, in line with our policy of not letting S affect the central values, we give the values of $\overline{P}_i$ obtained from the original (unscaled) fit.

There is one special case in which the errors that are obtained by the preceding procedure may be changed. When a fitted branching ratio (or rate) $\overline{P}_i$ turns out to be less than three standard deviations ($\delta\overline{P}_i^{\prime}$) from zero, a new smaller error $(\delta\overline{P}_i^{\prime\prime})^-$ is calculated on the low side by requiring the area under the Gaussian between $\overline{P}_i - (\delta\,\overline{P}_i^{\prime\prime})^-$ and $\overline{P}_i$ to be 68.3% of the area between zero and $\overline{P}_i$. A similar correction is made for branching fractions that are within three standard deviations of one. This keeps the quoted errors from overlapping the boundary of the physical region.

4.3. *Rounding*: While the results shown in the Particle Listings are usually exactly those published by the experiments, the numbers that appear in the Summary Tables (means, averages and limits) are subject to a set of rounding rules.

The basic rule states that if the three highest order digits of the error lie between 100 and 354, we round to two significant digits. If they lie between 355 and 949, we round to one significant digit. Finally, if they lie between 950 and 999, we round up to 1000 and keep two significant digits. In all cases, the central value is given with a precision that matches that of the error. So, for example, the result (coming from an average) 0.827 ± 0.119 would appear as 0.83 ± 0.12, while 0.827 ± 0.367 would turn into 0.8 ± 0.4.

Rounding is not performed if a result in a Summary Table comes from a single measurement, without any averaging. In that case, the number of digits published in the original paper is kept, unless we feel it inappropriate. Note that, even for a single measurement, when we combine statistical and systematic errors in quadrature, rounding rules apply to the result of the combination. It should be noted also that most of the limits in the Summary Tables come from a single source (the best limit) and, therefore, are not subject to rounding.

Finally, we should point out that in several instances, when a group of results come from a single fit to a set of data, we have chosen to keep two significant digits for all the results. This happens, for instance, for several properties of the W and Z bosons and the τ lepton.

4.4. *Discussion*: The problem of averaging data containing discrepant values is nicely discussed by Taylor in Ref. 4. He considers a number of algorithms that attempt to incorporate inconsistent data into a meaningful average. However, it is difficult to develop a procedure that handles simultaneously in a reasonable way two basic types of situations: (a) data that lie apart from the main body of the data are incorrect (contain unreported errors); and (b) the opposite—it is the main body of data that is incorrect. Unfortunately, as Taylor shows, case (b) is not infrequent. He concludes that the choice of procedure is less significant than the initial choice of data to include or exclude.

We place much emphasis on this choice of data. Often we solicit the help of outside experts (consultants). Sometimes, however, it is simply impossible to determine which of a set of discrepant measurements are correct. Our scale-factor technique is an attempt to address this ignorance by increasing the error. In effect, we are saying that present experiments do not allow a precise determination of this quantity because of unresolvable discrepancies, and one must await further measurements. The reader is warned of this situation by the size of the scale factor, and if he or she desires can go back to the literature (via the Particle Listings) and redo the average with a different choice of data.

Our situation is less severe than most of the cases Taylor considers, such as estimates of the fundamental constants like $\hbar$, *etc.* Most of the errors in his case are dominated by systematic effects. For our data, statistical errors are often at least as large as systematic errors, and statistical errors are usually easier to estimate. A notable exception occurs in partial-wave analyses, where different techniques applied to the same data yield different results. In this case, as stated earlier, we often do not make an average but just quote a range of values.

A brief history of early Particle Data Group averages is given in Ref. 3. Figure 2 shows some histories of our values of a few particle properties. Sometimes large changes occur. These usually reflect the introduction of significant new data or the discarding of older data. Older data are discarded in favor of newer data when it is felt that the newer data have smaller systematic errors, or have more checks on systematic errors, or have made corrections unknown at the time of the older experiments, or simply have much smaller errors. Sometimes, the scale factor becomes large near the time at which a large jump takes place, reflecting the uncertainty introduced by the new and inconsistent data. By and large, however, a full scan of our history plots shows a dull progression toward greater precision at central values quite consistent with the first data points shown.

We conclude that the reliability of the combination of experimental data and our averaging procedures is usually good, but it is important to be aware that fluctuations outside of the quoted errors can and do occur.

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2. Particle Data Group: M. Aguilar-Benitez *et al.*, Phys. Lett. **170B** (1986).
3. A.H. Rosenfeld, Ann. Rev. Nucl. Sci. **25**, 555 (1975).
4. B.N. Taylor, "Numerical Comparisons of Several Algorithms for Treating Inconsistent Data in a Least-Squares Adjustment of the Fundamental Constants," U.S. National Bureau of Standards NBSIR 81-2426 (1982).

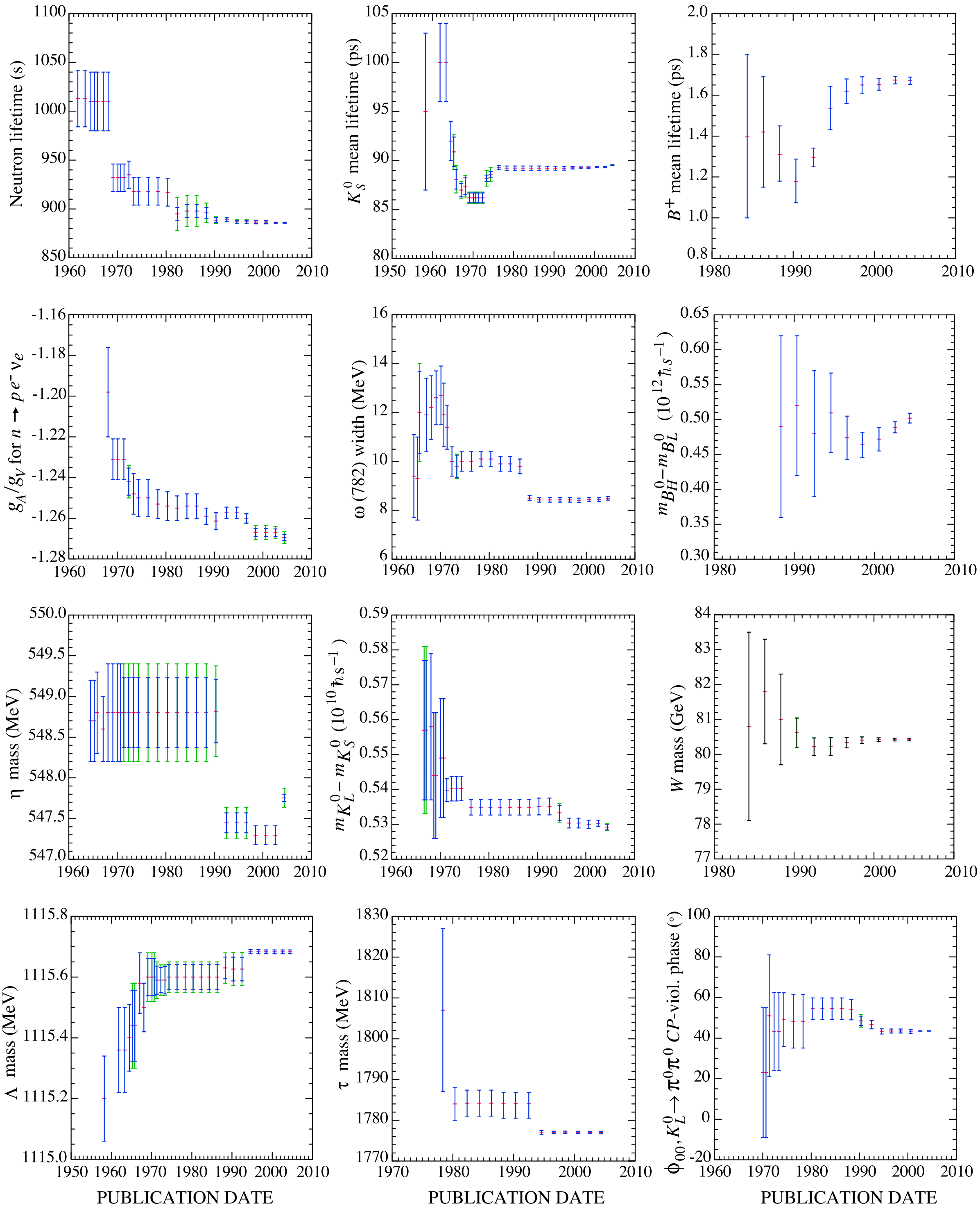

Figure 2: An historical perspective of values of a few particle properties tabulated in this *Review* as a function of date of publication of the *Review*. A full error bar indicates the quoted error; a thick-lined portion indicates the same but without the "scale factor."

ONLINE PARTICLE PHYSICS INFORMATION

Revised December 2003 by P. Kreitz (SLAC) with the substantial assistance in the Physics Education Section from L. Wolf (SLAC).

This annotated list provides a highly selective set of online resources that are useful to the particle physics community. It describes the scope, size, and organization of the resources so that efficient choices can be made amongst many sites which may appear similar. A resource is excluded if it provides information primarily of interest to only one institution. Because this list must be fixed in print, it is important to consult the updated version of this compilation which includes newly added resources and hypertext links to more complete information at:

`http://www.slac.stanford.edu/library/pdg/`

Accelerator physics resources have been excluded because they are covered well by the World Wide Web Virtual Library of Beam Physics and Accelerator Technology:

`http://home.earthlink.net/ whittum/vl/`

My thanks to Betty Armstrong and Piotr Zyla, Particle Data Group, Travis Brooks and Kim Sutton, SLAC Library, and the many particle physics Web site and database maintainers who have all given me their generous assistance. Please send comments and corrections by e-mail to `pkreitz@slac.stanford.edu`.

1. Particles & Properties Data:

- REVIEW OF PARTICLE PHYSICS (RPP): A biennial comprehensive review summarizing much of the known data about the field of particle physics produced by the international Particle Data Group (PDG). Includes a compilation/evaluation of data on particle properties, summary tables with best values and limits for particle properties, extensive summaries of searches for hypothetical particles, and a long section of reviews, tables, and plots on a wide variety of theoretical and experimental topics of interest to particle and astrophysicists. The linked table of contents provides access to particle listings, reviews, summary tables, errata, indices, *etc.* The current printed version is this edition: S. Eidelman, *et al.*, *Physics Letters* **B592** 1. Maintained at:
  `http://pdg.lbl.gov/`
- PARTICLE PHYSICS BOOKLET: A pocket-sized 300-page booklet containing the Summary Tables and abbreviated versions of some of the other sections of the full *Review of Particle Physics.* This is extracted from the most recent edition of the full *Review of Particle Physics.* Contains images in an easy-to-read print useful for classroom studies. The next edition will be in Spring 2004. Until the new edition is published and available via the Web, students, teachers, and researchers should use the full *Review of Particle Physics*:
  `http://pdg.lbl.gov/`
- COMPUTER-READABLE FILES: Currently available from the PDG: Tables of masses, widths, and PDG Monte Carlo particle numbers and cross-section data, including hadronic total and elastic cross sections vs laboratory momenta, and total center-of mass energy. The PDG Monte Carlo particle numbering scheme has been updated for the recent edition of the RPP and are also available as a MobileDB database. Palm Pilot products include physical constants, astrophysical constants and particle properties. These files are is updated in even-numbered years coinciding with the production of the *Review of Particle Properties*:
  `http://pdg.lbl.gov/computer_read.html`
- PARTICLE PHYSICS DATA SYSTEM: This site contains an indexed bibliography of particle physics (1895–1995), a database of computerized numerical data extracted from experimental publications, and an index of papers (1895–present) that contain experimental data or data analyses. The Web interface permits simple searching for for compilations of integrated cross-section data. The search interface for numerical data on observables in reactions (ReacData or RD), is under construction. Maintained by the COMPAS group at IHEP:
  `http://wwwppds.ihep.su:8001/ppds.html`
- HEPDATA: REACTION DATA DATABASE: A part of the HEPDATA databases at University of Durham/RAL, this database is compiled by the Durham Database Group (UK) with help from the COMPAS Group (Russia) for the PDG. Contains numerical values of HEP reaction data such as total and differential cross sections, fragmentation functions, structure functions, and polarization measurements from a wide range of experiments. Updated at regular intervals. Provides data reviews which contain precompiled reviewed data such as 'Structure Functions in DIS', 'Single Photon Production in Hadronic Interactions', and 'Drell-Yan Cross Sections':
  `http://durpdg.dur.ac.uk/HEPDATA/REAC`
- NIST PHYSICS LABORATORY: This unit of the National Institute of Standards and Technology provides measurement services and research for electronic, optical, and radiation technologies. Three sub-pages, on Physical Reference Data, on Constants, Units & Uncertainty, and on Measurements & Calibrations, are extremely useful. Additional links to other physical properties and data of tangential interest to particle physics are also available from this page:
  `http://physics.nist.gov/`

2. Collaborations & Experiments:

- EXPERIMENTS Database: Contains more than 2,200 past, present, and future experiments in elementary particle physics. Lists both accelerator and non-accelerator experiments. Includes official experiment name and number, location, spokespersons and collaboration lists. Simple searches by: participant, title, experiment number, institution, date approved, accelerator, or detector, return a result that fully describes the experiment, including a complete list of authors, title, description of the experiment's goals and methods, and a link to the experiment's Web page if available. Publication lists distinguish articles in refereed journals, theses, technical or instrumentation papers, and those which make the Topcite at 50+ subsequent citations or more:
  `http://www.slac.stanford.edu/spires/experiments/`
- HIGH ENERGY PHYSICS EXPERIMENTS: A HEPiC page of links to experimental collaboration Web pages. Experiments are arranged alphabetically by name or number under 18 major laboratories or in a miscellaneous group of 'Others':
  `http://www.hep.net/experiments/all_sites.html_sites.html`
- COSMIC RAY/GAMMA RAY/NEUTRINO AND SIMILAR EXPERIMENTS: This is an extensive collection of experimental Web sites organized by focus of study and also by location. Additional sections link to educational materials, organizations and related Web sites, *etc.* Maintained at the Max Planck Institute for Nuclear Physics by Konrad Bernlöhr:
  `www.mpi-hd.mpg.de/hfm/CosmicRay/CosmicRaySites.html`

3. Conferences:

- CONFERENCES: Database of more than 12,300 past, present and future conferences, schools, and meetings of interest to high-energy physics and related fields. Covers 1973 to the future. The current year covers more than 600 events. Search or browse by title, acronym, date, location. Includes information about published proceedings, links to submitted papers from the SPIRES-HEP database, and links to the conference Web site when available. Links to a form with which one can submit a new conference or edit an existing one:
  `http://www.slac.stanford.edu/spires/conferences/add_conference.shtml` to submit a new conference. Can also search for any conferences occurring by day, month, quarter, or year:
  `http://www.slac.stanford.edu/spires/conferences/`

- CONFERENCES AND CONFERENCES: Lists 150+ current meetings in many fields of physics. Provides post-conference information such as proceedings, *etc.*, in a second list at the end of the subject categories of conferences. Browse through an ASCII list of all conferences or specialized lists arranged by topic: particles/nuclei, quantum, condensed matter, mathematical, interdisciplinary physics, and related fields. Includes links to the conference Web page and the contact. Provides a useful set of links to universities, laboratories and institutions which host major conferences and/or schools:
  `http://www.physics.umd.edu/robot/confer/confmenu.html`
- CERN EVENTS: A list of current and upcoming conferences, schools, workshops, *etc.*, of interest to high-energy physicists. Organized by year and then by date. Covers from 1993 to one year beyond the current year. Includes about a hundred events. To post an event to this list use the Web form at:
  `http://wpedb.cern.ch/databases/requests/`
- EUROPHYSICS MEETINGS LIST: Maintained by the European Physical Society, this lists in chronological order all the current and future meetings, workshops, schools, *etc.*, organized or sponsored by EPS or organized in conjunction with an EPS-sponsored group. Provides a PDF form to electronically submit a notice of a new conference or to print and mail to EPS:
  `http://www.eps.org/ephconf.html`
- PHYSICSWEB EVENTS: Part of the Institute of Physics (IOP) Web site, this site contains approximately a hundred entries for meetings, workshops, exhibitions and schools occurring in the current year and the following year. Fills a gap by covering the smaller conferences and workshops around the world. Searchable by type of event, e.g., school, workshop, or by date or free text words. Provides a Web form and email address for adding a conference and for signing up to receive email notices of new events added:
  `http://physicsweb.org/events/`

4. Current Notices & Announcement Services:

- See also the conference and event sites above for links to email notification services or event submission forms.
- CURRENT SCIENCE NEWS: Lists news sites from around the world. A few sites are by subscription and so are labelled as available to Stanford only but most are free and publically accessible. Commercial sites often provide headlines and a brief abstract as a free service and require subscription or payment for a complete article.
  `http://www.slac.stanford.edu/library/eresources/news.html`
- E-PRINT ARCHIVES LISTSERV NOTICES: The Cornell-based E-Print Archives provides daily notices of preprints in the fields of physics, mathematics, nonlinear sciences, and computer sciences and quantitative biology which have been submitted to the archives as full text electronic documents. Use the Web-accessible listings:
  `http://arXiv.org/`
  or subscribe:
  `http://arXiv.org/help/subscribe`
- HEPJOBS DATABASE: Maintained by Fermilab and SLAC libraries, this database lists jobs in the fields of core interest to the particle physics and astroparticle physics communities. Use this page to post a job or to receive email notices of new job listings:
  `http://www.slac.stanford.edu/spires/jobs/`
- INTERACTIONS.ORG: Provides particle physics news and resources from the world's particle physics laboratories. Subscribe to Interactions.org Newswire:
  `http://www.interactions.org/cms/?pid=1000502`
- NASA ASTROPHYSICS DATA SYSTEM: This table of contents query page provides tables of contents for 24 core titles in the field:
  `http://adsabs.harvard.edu/custom_toc.html`
- PREPRINTS IN PARTICLES AND FIELDS (PPF): A weekly listing averaging 250 new preprints in particle physics and related fields. Contains bibliographic listings for and, in the Web version, full text links to, the new preprints received by and cataloged into the SPIRES High-Energy Physics (HEP) database. Includes that week's titles from the e-print archives as well as preprints and articles received from other sources. Directions for subscribing to an email version can be found on the page listing the most recent week's preprints:
  `http://www.slac.stanford.edu/library/documents/newppf.html`
- PSIGATE PHYSICS GATEWAY: IoP News and Jobs: Newsfeeds containing the latest jobs and news from the Institute of Physics' (IoP) PhysicsWeb with news headlines from Optics.org, Fibers.org and Nanotechweb.org:
  `http://www.psigate.ac.uk/newsite/awareness_iop.html`

Note: Use the library pages in Section 5.3 below to find additional announcement lists for recently received preprints, books, and proceedings. Use the online journal links in Section 7 below for journal table of contents.

5. Directories:

5.1. *Directories—Research Institutions:*

- HEP and Astrophysics INSTITUTIONS: SPIRES database of over 6,500 high-energy physics and astropartcle physics institutes, laboratories, and university departments in which research on particle physics is performed. Covers six continents and over a hundred countries. Provides an alphabetical list by country or an interface that is searchable by name, acronym, location, *etc.* Includes address, phone and fax numbers, e-mail address, and Web links where available. Has links to the recent HEP papers from each institution. Maintained by SLAC, DESY and Fermilab libraries:
  `http://www.slac.stanford.edu/spires/institution/`
- HEP INSTITUTES: Contains almost a thousand institutional addresses used in the CERN Library catalog. Includes, where available, the following: phone and fax numbers; e-mail addresses; and Web links. Provides free text searching and result sorting by organization, country, or town:
  `http://cdsweb.cern.ch/?c=HEP%20Institutes`
- HIGH ENERGY PHYSICS WEB SITES: An alphabetical listing of approximately 200 particle physics Web sites with links to the institutions' Web pages. Maintained by the CERN Web group for the WWW Virtual Library. Somewhat difficult to use because entries are listed by institutional acronym or by short name:
  `http://physics.web.cern.ch/physics/HEPWebSites.html`
- TOP 500 INSTITUTIONS IN HIGH-ENERGY PHYSICS: Lists the 500 HEP-related organizations and universities that have published the most papers in the past five years, as identified from the SPIRES HEP Database. Provides active links to the home pages and full INSTITUTIONS database records. Listed by country, and then alphabetically by institution:
  `http://www.slac.stanford.edu/spires/institution/major.shtml`

5.2. *Directories—People:*

- HEPNAMES: Searchable worldwide database of over 40,000 people associated with particle physics, synchrotron radiation, and related fields. Provides e-mail addresses, country in which the person is currently working, and a SPIRES HEP database search for their papers. If the person has supplied the following information, it lists the countries in which they did their undergraduate and graduate work, their url, and their graduate students. It also provides listings of Nobel Laureates, country statistics, Lab Directors, *etc.*:
  `http://www.slac.stanford.edu/spires/hepnames/`
- HEP VIRTUAL PHONEBOOK: A list of links to phonebooks and directories of high-energy physics sites and collaborations around the world organized by site. Often provides links to more specialized phone or e-mail listings, such as a department within a university, visiting scientists, or postdocs. Some phonebooks may require passwords or other authentication to access. Maintained by HEPiC:
  `http://www.hep.net/sites/directories.html`
- US-HEPFOLK DIRECTORY: A searchable directory and census of U.S. particle physicists updated annually. Contains more than 4,000 U.S. physicists. Searchable by first or last name, by affiliation, and/or by email address. Also provides demographic plots of the survey data for the past three years:
  `http://pdg.lbl.gov/us-hepfolk/index.html`

5.3. *Directories—Libraries:*

- Argonne National Laboratory (ANL) Library:
  `http://www.library.anl.gov/library/index.html`
- Brookhaven National Laboratory (BNL) Library:
  `http://inform.bnl.gov/RESLIB/reslib.html`
- (CERN) European Organization for Nuclear Research Library:
  `http://library.cern.ch/`
- Deutsches Elektronen-Synchrotron (DESY) Library:
  `http://www.desy.de/html/infodienste/bibliothek.html`
- Fermi National Accelerator Laboratory (Fermilab) Library:
  `http://fnalpubs.fnal.gov/`
- Idaho National Engineering and Environmental Laboratory (INEEL) Library:
  `http://www.inel.gov/library/`
- (KEK) National Laboratory for High Energy Physics Library:
  `http://www-lib.kek.jp/top-e.html`
- Lawrence Berkeley National Laboratory (LBNL) Library:
  `http://www-library.lbl.gov/teid/tmLib/aboutus/LibDefault.htm`
- Lawrence Livermore National Laboratory (LLNL) Library:
  `http://www.llnl.gov/library/`
- Los Alamos National Laboratory (LANL) Library:
  `http://lib-www.lanl.gov/`
- Oak Ridge National Laboratory (ORNL) Library:
  `http://www.ornl.gov/Library/library-home.html`
- Pacific Northwest National Laboratory (PNL) Library:
  `http://www.pnl.gov/tech_lib/home.html`
- Sandia National Laboratory Library:
  `http://www.sandia.gov/news-center/resources/tech-library/index.html`
- Stanford Linear Accelerator Center (SLAC) Library:
  `http://www.slac.stanford.edu/library`
- Thomas Jefferson National Accelerator Facility (JLab) Library:
  `http://www.jlab.org/IR/library/index.html`

5.4. *Directories—Publishers:*

- DIRECTORY OF PUBLISHERS AND VENDORS: Outstanding and comprehensive directory of publishers and vendors used by libraries. Organized by publisher name, by subject (e.g. Science, Mathematics, and Technology), and by location. Also provides an email directory.
  `http://acqweb.library.vanderbilt.edu/acqweb/pubr.html`

5.5. *Directories—Scholarly Societies:*

- American Association for the Advancement of Science:
  `http://www.aaas.org/`
- American Association of Physics Teachers:
  `http://www.aapt.org/`
- American Astronomical Society:
  `http://www.aas.org`
- American Institute of Physics:
  `http://www.aip.org/`
- American Mathematical Society:
  `http://www.ams.org/`
- American Physical Society:
  `http://www.aps.org`
- American Physical Society: Scholarly Societies: Use this list to find national and international scientific and professional societies:
  `http://www.aps.org/resources/society.html`
- European Physical Society:
  `http://epswww.epfl.ch/`
- IEEE Nuclear and Plasma Sciences Society:
  `http://ewh.ieee.org/soc/nps/aboutnpss.htm`
- Institute of Physics:
  `http://www.iop.org/`
- International Union of Pure and Applied Physics:
  `http://www.iupap.org/`
- Japan Society of Applied Physics:
  `http://www.jsap.or.jp/english/`
- Physical Society of Japan:
  `http://wwwsoc.nii.ac.jp/jps/`
- Physical Society of the Republic of China:
  `http://psroc.phys.ntu.edu.tw/english/index.html`
- SCHOLARLY SOCIETIES PROJECT: Directory of more than 3,700 scholarly and technical societies with links to their Web sites. Permits searching by subject, country, language, founding dates, and more. Includes acronyms and indicates when a Web site contains both its native language and an English-language version and when it has a permanent URL. Provides direct links to society meeting and conference announcement lists, standards, and full text journals. Maintained by the University of Waterloo:
  `http://www.scholarly-societies.org/`

6. E-Prints/Pre-Prints, Papers, & Reports:

- CERN ARTICLES & PREPRINTS: The CERN document server contains records of more than 500,000 CERN and non-CERN articles, preprints, theses. Includes records for CERN Yellow Reports, internal and technical notes, and official CERN committee documents. Provides access to full text of the documents for about 50 percent of the entries and to the references when available:

  `http://cdsweb.cern.ch/?c=Articles+%26+Preprints&as=0`

- ECONF: Electronic Conference Proceedings Archive: This site offers a fully electronic, Web-accessible archive for the proceedings of scientific conferences in High-Energy Physics and related fields. Conference editors can use the site tools to prepare and post an electronic version of their proceedings. Librarians and other indexers can download metadata from each proceedings. Researchers can browse an entire proceedings via a table of contents or search for papers through a link to the SPIRES HEP Database which indexes the EConf contents.

  `http://www.slac.stanford.edu/econf/`

- HEP DATABASE (SPIRES): Contains over 570,000 bibliographic records for particle physics articles, including journal papers, preprints, e-prints, technical reports, conference papers and theses. Comprehensively indexed with multiple links to full text as well as links to author and institutional information. Covers 1974 to the present with substantial older materials added. Updated daily with links to electronic texts, Durham Reaction Data, *Review of Particle Properties*, *etc.* Searchable by citation, by all authors and authors' affiliations, title, topic, report number, citation (footnotes), e-print archive number, date, journal, *etc.* A joint project of the SLAC and DESY libraries with the collaboration of Fermilab, Durham University (UK), KEK, Kyoto University, and many other research institutions and scholarly societies:

  `http://www.slac.stanford.edu/spires/hep/`

- JACoW: This Joint Accelerator Conference Website is organized by the editorial boards of the Asian, European and American Particle Accelerator Conferences and the CYCLOTRONS, DIPAC, ICALEPCS and LINAC conferences. It contains the full text of all the papers of these accelerator conferences. Search by conference name, author, title, keyword or full text of the paper:

  `http://www.JACoW.org/`

- KISS (KEK INFORMATION SERVICE SYSTEM) FOR PREPRINTS: KEK Library preprint and technical report database. Contains bibliographic records of preprints and technical reports held in the KEK library with links to the full text images of more than 100,000 papers scanned from their worldwide collection of preprints. Particularly userful for older scanned preprints:

  `http://www-lib.kek.jp/KISS/kiss_prepri.html`

- E-PRINT ARCHIVE: The arXiv.org's automated electronic repository of full text papers in physics, mathematics, computer, and nonlinear sciences and cosmology and quantitative biology. Papers, called pre-prints or e(electronic)-prints, are usually sent by their authors to arXiv in advance of submission to a journal for publication. Primarily covers 1991 to the present but authors are encouraged to post older papers retroactively. Permits searching by author, title, and keyword in abstract. Allows limiting by subfield archive or by date.

  `http://arXiv.org`

- NASA ASTROPHYSICS DATA SYSTEM: The ADS Abstract Service provides a search interface for four bibliographic databases covering: Astronomy and Astrophysics, Instrumentation, Physics and Geophysics, and arXiv Preprints. Contains abstracts from articles and monographs as well as conference proceedings:

  `http://adsabs.harvard.edu/ads_abstracts.html`

- PARTICLE PHYSICS DATA SYSTEM—PPDS: A search interface to the bibliography of the print publication *A Guide to Experimental Elementary Particle Physics Literature* (LBL-90). This bibliography covers the published literature of theoretical and experimental particle physics from 1895 to 1995. The url is sometimes difficult to reach:

  `http://wwwppds.ihep.su:8001/ppds.html`

- DIRECTORY OF MATHEMATICS PREPRINT AND E-PRINT SERVERS: Provides the current home page and email contacts for mathematical preprint and e-print servers throughout the world:

  `http://www.ams.org/global-preprints/`

7. Particle Physics Journals & Reviews:

7.1. *Online Journals and Tables of Contents:*

Please note, some of these journals, publishers, and reviews may limit access to subscribers. If you encounter access problems, check with your institution's library.

- ADVANCES IN THEORETICAL AND MATHEMATICAL PHYSICS (ATMP): Bimonthly electronic and hard copy publication. Table of contents has links to arXiv.org since this is the first e-journal to be an overlay to arXiv.org, where papers for this journal are submitted:

  `http://www.intlpress.com/journals/ATMP/archive/`

- AMERICAN JOURNAL OF PHYSICS: A monthly publication of the American Association of Physics Teachers on instructional and cultural aspects of physical science:

  `http://ojps.aip.org/ajp`

- APPLIED PHYSICS LETTERS: Weekly publication of short (3 pages maximum) articles:

  `http://ojps.aip.org/aplo/`

- ASTROPHYSICAL JOURNAL: Published three times a month by the American Astronomical Society (AAS). See also AAS entry under Journal Publishers (below):

  `http://www.journals.uchicago.edu/ApJ/`

- CLASSICAL AND QUANTUM GRAVITY: Published 24 times a year by the Institute of Physics (IOP) covering the fields of gravitation and spacetime theory:

  `http://www.iop.org/Journals/cq`

- EUROPEAN PHYSICAL JOURNAL A: HADRONS AND NUCLEI: This monthly journal merges *Il Nuovo Cimento A* and *Zeitschrift fur Physik A* and covers physics and astronomy:

  `http://www.springerlink.com/app/home/journal.asp?wasp=hb5c1gugrj2rwcvkybrl&referrer=parent&backto=linkingpublicationresults,id:101158,1`

- EUROPEAN PHYSICAL JOURNAL C: PARTICLES AND FIELDS: This twice monthly journal is the successor to *Zeitschrift fur Physik C*, covering physics and astronomy:

  `http://www.springerlink.com/app/home/journal.asp?wasp=4nc6tkmvqh3qgyjvudu7&referrer=parent&backto=linkingpublicationresults,id:101160,1`

- INTERNATIONAL JOURNAL OF MODERN PHYSICS C: PHYSICS AND COMPUTERS: Includes both revew and research articles. Published ten times per year:

  `http://ejournals.wspc.com.sg/ijmpc/ijmpc.shtml`

- INTERNATIONAL JOURNAL OF MODERN PHYSICS D: GRAVITATION, ASTROPHYSICS AND COSMOLOGY: Includes both revew and research articles. Published ten times per year:

  `http://ejournals.wspc.com.sg/ijmpd/ijmpd.shtml`

- INTERNATIONAL JOURNAL OF MODERN PHYSICS E: NULCEAR PHYSICS: Includes both revew and research articles. Bi-monthly:

  `http://ejournals.wspc.com.sg/ijmpe/ijmpe.shtml`

- JAPANESE JOURNAL OF APPLIED PHYSICS: Part 1 is monthly and covers papers, short notes, and review papers. Part 2 is semimonthly and publishes letters including a special *Express Letters* section:

  `http://www.jsap.or.jp/english/publication/journal.html`

- JOURNAL OF COSMOLOGY AND ASTROPARTICLE PHYSICS: An electronic peer-reviewed journal created by the International School for Advanced Studies (SSISA) and the Institute of Physics. Authors are encouraged to submit media files to enhance the online versions of articles:

  `http://jcap.sissa.it/`

- JOURNAL OF HIGH ENERGY PHYSICS: Electronic and print available. Like *ATMP*, this is a refereed journal written, run, and distributed by electronic means. It accepts email submission notices and 'fetches' the submitted paper from the arXiv.org E-print archives:

  `http://jhep.sissa.it/`

- JOURNAL OF PHYSICS G: NUCLEAR AND PARTICLE PHYSICS: Monthly, published by IOP:

  `http://www.iop.org/EJ/journal/0954-3899`

- JOURNAL OF THE PHYSICAL SOCIETY OF JAPAN: JPSJ ONLINE: Monthly, online since 1996:

  `http://jpsj.ipap.jp/`

- MODERN PHYSICS LETTERS A: Published 40 times a year, this contains research papers in gravitation, cosmology, nuclear physics, and particles and fields. *Brief Review* section for short reports on new findings and developments:

  `http://www.wspc.com.sg/journals/mpla/mpla.html`

- NEW JOURNAL OF PHYSICS: Co-owned by the Institute of Physics and the Deutsche Physikalische Gesellschaft, this journal is funded by article charges from authors of published papers and by scholarly societies, *NJP* is available in a free, electronic form:

  `http://www.iop.org/EJ/journal/1367-2630/1`

- NUCLEAR INSTRUMENTS AND METHODS IN PHYSICS RESEARCH A: ACCELERATORS, SPECTROMETERS, DETECTORS, AND ASSOCIATED EQUIPMENT: This journal was formerly part of *Nuclear Instruments and Methods in Physics Research.* Published approximately 36 times per year, this journal covers instrumentation and large scale facilities:

  `http://www.elsevier.nl/locate/nima`

- NUCLEAR PHYSICS A: NUCLEAR AND HADRONIC PHYSICS:

  `http://www.elsevier.nl/inca/publications/store/5/0/5/7/1/5/`

- NUCLEAR PHYSICS B: PARTICLE PHYSICS, FIELD THEORY, STATISTICAL SYSTEMS, AND MATHEMATICAL PHYSICS:

  `http://www.elsevier.nl/inca/publications/store/5/0/5/7/1/6/`

- NUCLEAR PHYSICS B: PROCEEDINGS SUPPLEMENTS: Publishes proceedings of international conferences and topical meetings in high-energy physics and related areas:

  `http://www.elsevier.nl/inca/publications/store/5/0/5/7/1/7/`

- PHYSICAL REVIEW D: PARTICLES, FIELDS, GRAVITATION, AND COSMOLOGY: Published 24 times a year:

  `http://prd.aps.org/`

- PHYSICAL REVIEW SPECIAL TOPICS – ACCELERATORS AND BEAMS: A peer-reviewed electronic journal freely available from the American Physical Society:

  `http://prst-ab.aps.org/`

- PHYSICS LETTERS B: Nuclear and Particle Physics: Published weekly:

  `http://www.elsevier.nl/locate/plb`

- PHYSICS—USPEKHI: English edition of *Uspekhi Fizicheskikh Nauk*:

  `http://ufn.ioc.ac.ru/`

- PROGRESS IN PARTICLE AND NUCLEAR PHYSICS: Published four times a year. Many, but not all, articles are at a level suitable for the general nuclear and particle physicist:

  `http://www.elsevier.nl/locate/inca/419`

- PROGRESS OF THEORETICAL PHYSICS: Published monthly covering all fields of theoretical physics. A supplement is published roughly quarterly containing either long original or review papers or collections of papers on specific topics:

  `http://www2.yukawa.kyoto-u.ac.jp/ ptpwww/`

7.2. *Journals – Directories:*

- DESY Library Electronic Journals: Use this Web page for up-to-date links to electronic journals of interest to particle physics. Provides a further link to tables of contents services. Provides a broader list than is included in this compilation:

  `http://www-library.desy.de/eljnl.html`

7.3. *Journals – Publishers & Repositories:*

- NASA ASTROPHYSICS DATA SYSTEM: Provides free electronic access to back issues of the *Astrophysical Journal*, *Astrophysical Journal Letters*, and the *Astrophysical Journal Supplement Series* and to many other titles. Often a journal allows the ADS to provide free, full text access after a delay of some number of years. :

  `http://adswww.harvard.edu/`

- AIP JOURNAL CENTER: The American Institute of Physics' top-level page for their electronic journals may be found at:

  `http://www.aip.org/ojs/service.html`

- AMERICAN PHYSICAL SOCIETY: The top-level page for the APS research journals. From this page one can access their *Physical Review* Online Archive (PROLA) search engine which is free to users:

  `http://publish.aps.org/`

- ELSEVIER SCIENCE: This Web site enables browsing Elsevier-published journals by subject field. First select Physics and Astronomy and then on the next page you must select either physics or astronomy (no longer both) and then subsequently select a sub-field of physics or astronomy. This page permits one to also select publication type Journal. Then, one reaches an alphabetical listing of journal titles with links to the journal's home page:

  `http://www.elsevier.nl/homepage/`

- EUROPEAN PHYSICAL SOCIETY: This is the top-level page listing all the society's journals:

  `http://www.eps.org/publications.html`

- INSTITUTE OF PHYSICS (IOP): Journals: Information: A list of the IOP journals organized by subject. A page organized by title is also available linked to this page:

  `http://www.iop.org/EJ/S/3/418/main/-list=subject`

- SPRINGER PUBLISHING: Physics: From this link, one can reach a subject list of Springer journals in physics with two more clicks. Unfortunately, the URL to that page is prohibitively long and so this is the most practical route:
  `http://www.springer-ny.com/discipline.tpl?discipline=Physics&cart=10715351791679624`

7.4. *Review Publications:*

- LIVING REVIEWS IN RELATIVITY: A peer-refereed, solely online physics j ournal publishing invited reviews covering all areas of relativity. Provided as a free service to the scientific community. Published in yearly volumes, although articles appear throughout the year. Hyperlinks are kept checked and active and reviews are updated frequently:
  `http://relativity.livingreviews.org/`
- NET ADVANCE OF PHYSICS: A free electronic service providing review articles and tutorials in an encyclopedic format. Covers all areas of physics. Includes e-prints, book announcements, full text of electronic books, and other resources with hypertext links when available. Welcomes contributions of original review articles:
  `http://web.mit.edu/redingtn/www/netadv/welcome.html`
- PHYSICS REPORTS: A review section for *Physics Letters A* and *Physics Letters B*. Each report deals with one subject. The reviews are specialized in nature, more extensive than a literature survey but normally less than book length:
  `http://www.elsevier.nl/locate/physrep`
- REPORTS ON PROGRESS IN PHYSICS: Covers all areas of physics and is published monthly. All papers are free for 30 days from the date of online publication:
  `http://www.iop.org/EJ/journal/0034-4885/1`
- REVIEWS OF MODERN PHYSICS: Published quarterly, it includes traditional scholarly reviews and shorter colloquium papers intended to describe recent research of interest to a broad audience of physicists:
  `http://rmp.aps.org/`

8. Particle Physics Education Sites:

Please note, each site in this section containing student activities now lists the (U.S. educational system) school grade level(s) that best fit that site. Also listed are the National Science Education Content Standards for teaching science which are relevant to the classroom activities provided at that site. Further explanation of the National Science Educational Content Standards can be found at:

For Grades 5 - 8:
`http://www.nap.edu/readingroom/books/nses/html/6d.html`

For Grades 9 - 12:
`http://www.nap.edu/readingroom/books//nses/html/6e.html`

8.1. *Particle Physics Education: Background Knowledge:*

- ANTIMATTER: MIRROR OF THE UNIVERSE: Find out what antimatter is, where it is made, the history behind its discovery, and how it is a part of our lives. This award-winning site, sponsored by the European Organisation for Nuclear Research, (CERN), explains to big kids and little kids alike the truth (and fiction) about antimatter. Features colorful photos and illustrations, a Kids Corner, and CERN physicists answering your questions on antimatter.
  Grades 8-12+; National Science Education Content Standards: A, B, D, G
  `http://livefromcern.web.cern.ch/livefromcern/antimatter/index.html`
- BIG-BANG SCIENCE–EXPLORING THE ORIGINS OF MATTER: In clear, concise, yet elegant language, this Web site, produced by the Particle Physics and Astronomy Research Council of the UK (PPARC), explains what physicists are looking for with their giant instruments called accelerators and particle detectors. Includes a brief history on how scientists came to define what is fundamental in the universe. Big Bang Science focuses on CERN particle detectors and on United Kingdom scientists' contribution to the search for the fundamental building blocks of matter. In addition to information on the how and why of particle physics, this site also shows particle physics as an international collaborative endeavor.
  Grades 9-12; National Science Education Content Standards B, D, E, G
  `http://hepwww.rl.ac.uk/pub/bigbang/part1.html`
- LIFE, THE UNIVERSE, AND THE ELECTRON: Sponsored by the Institute of Physics (IOP) and the Science Museum, London, this interactive online exhibit celebrates the centenary of the discovery of the electron. Sections explain many aspects of the nature, history, and usefulness of electrons. Clear explanations and beautiful photography.
  Grades 9-12; National Science Education Content Standards: A, B, D
  `http://www.sciencemuseum.org.uk/on-line/electron/index.asp`
- THE WORLD OF BEAMS: A site to visit if you wish to know a little or a lot about laser beams, particle beams, and other kinds of beams. Includes interactive tutorials, such as: What are Beams?, Working with Beams, and Beam Research and Technology. A good resource for physical science units involving energy, structure and properties of matter, and motion and forces for Grades 8-12. The information here is also helpful if you plan to tour any of the national laboratories listed in the "Libraries" section of this guide.
  Grades 8-12; National Science Education Content Standards: A, B, E
  `http://cbp-1.lbl.gov/`

8.2. *Particle Physics Education: Particle Physics Lessons and Activities:*

- BNL/BSA ONLINE CLASSROOM: The objective of this site, developed by Brookhaven National Laboratory, is to use technology to bring the scientific research of BNL to students and teachers. BNL has created a series of nine units comprising an online, interactive classroom and provided a Multi User Object-Oriented (MOO) virtual classroom that enables group interactivity. Students can test their knowledge of physics by playing the delightfully interactive RHIC Adventure (Secrets of the Nucleus) that focuses on the science of the Relativistic Heavy Ion Collider. Games can be modified to match student knowledge levels from grades 8-12. Lesson plans are available on nuclear physics for high school and on solar neutrinos for K-8. Try The Mystery of the Sun for grades K-8 or Dippin' Dots Neutrinos for grades 9-12. Each lesson includes National Science Education Content Standards.
  Grades K-12 (mostly 9-12); National Science Education Content Standards 5-8 and 9-12: A, B, D, E, G
  `http://onlineclassroom.bnl.org/`
- CONTEMPORARY PHYSICS EDUCATION PROJECT (CPEP): This site is especially designed to help teachers bring four areas of physics to their students in an accessible and engaging format. Provides charts, brochures, Web links, and classroom activities. Online interactive courses include: Fundamental Particles and Interactions (includes lesson plans), Plasma Physics and Fusion, and Nuclear Science (includes lesson plans and simple experiments).
  Grade Level: 9-12; Some of the experiments may be of interest to grades 5-8; National Science Education Content Standards 9-12: A, B, D, E
  `http://www.cpepweb.org/`

- CENTER FOR PARTICLE ASTROPHYSICS ON-LINE DEMOS: A good source for do-it-yourself demos aimed at middle school students (modifiable for other levels). Demonstrations include: Air-Powered Rockets, Desktop Stars, Lunar Topography, Ping Pong Ball Launcher, Potato Power, and Solar System. Each includes an introduction, teacher and student worksheets, and a list of materials needed. Site has not been updated with new materials, but existing lesson plans are nevertheless well-written and relevant. Parents might be interested in doing some of these projects with their children.
  Grades 7-8+; National Science Education Content Standards: A, B, D, E
  `http://cfpa.berkeley.edu/Education/DEMOS/DEMOS.html`

- DOE ONLINE K-12 INSTRUCTIONAL RESOURCES: The U.S. Department of Energy (DOE) brings together a collection of online resources and lesson plans from the education sites of DOE-funded national laboratories such as Stanford Linear Accelerator Center, Lawrence Berkeley, Jefferson Lab, and Brookhaven. In the area of atomic and particle physics, see Jefferson Lab's All About Atoms slide show and clickable interactive table of elements which enables you to find out an element's properties, history, and uses.
  Grades: K-12; A variety of lesson plans are available in all scientific disciplines, conforming to National Science Education Content Standards.
  `http://www-ed.fnal.gov/doe/`

- FERMILAB EDUCATION OFFICE: Outstanding collection of resources from the "grandmother" of all physics lab educational programs. Thoughtful unit and lesson plans in both physics and the environment (Fermilab is located on a rare, protected prairie in Illinois). Sections are organized by grade level. Note in particular pedagogical resources for teachers, LInC Online, and the Lederman Science Center. Offers online guided tours and and science adventures.
  Grades K-12; National Science Education Content Standards: A, B, C, D, E, F. Many lesson plans designed to meet Illinois State Standards
  `http://www-ed.fnal.gov/`

- GLAST CLASSROOM MATERIALS: The Gamma Ray Large Area Space Telescope (GLAST) project and the National Aeronautics and Space Administration (NASA)'s Education and Public Outreach Office have developed this colorful, in depth, and engaging Web site teaching about the origin and structure of the universe and the fundamental relationship between energy and matter. Includes lesson plans and a teacher resource booklet which are available in PDF format, HTML, or can be ordered in print. Lesson plans are hands-on, student-group oriented and require common household objects. Activities such as: Three Mysteries, Alien Bandstand, Live! From 2-Alpha, and Starmarket build critical thinking and analytical skills as well as address at least one of the physical science standards. Full color posters and other educational materials also available. Provides links to other educational Web sites with classroom resources.
  Grades 9-12; National Science Education Content Standards A, B, D, E
  `http://glast.sonoma.edu/teachers/teachers.html`

- IMAGINE THE UNIVERSE: Created by the Laboratory for High-Energy Astrophysics at NASA/Goddard Space Flight Center, this site features astronomy and astrophysics lesson plans for age 14 and up, teacher's guides, classroom posters, and links to other classroom resources. Activities are linked to National Standards for Science and Math. Lessons include: What is Your Cosmic Connection to the Elements?, Life Cycle of Stars, and Gamma-Ray Bursts. Also included in the Teacher's Corner are links to math-science lesson plans for grades 6-12. The Multimedia Theatre Archive provides more than a dozen movies with free downloadable viewing software.
  Grades 9-12; National Science Education Content Standards: A, B, D, G
  `http://imagine.gsfc.nasa.gov`

- *Also note:* STARCHILD: Interlinked with Imagine the Universe, above, this site is a lively, age appropriate site for grade school level astronomy lessons.
  `http://starchild.gsfc.nasa.gov/docs/StarChild/StarChild.html`

- JEFFERSON LAB SCIENCE EDUCATION: This well-organized, visually attractive Web site from the Thomas Jefferson National Accelerator Facility, supports science and math education in K-12 classrooms. Features hands-on physics activities, math games, and puzzles. Check out the All About Atoms slide show and the interactive Table of Elements. Includes a question-and-answer page on Atoms, Elements and Molecules and one on Electricity and Magnetism. Science videos are available on loan.
  Grades K-12; Lessons follow Virginia State and National Science Education Content Standards
  `http://education.jlab.org/`

- PHYSICAL SCIENCE HOTLIST: Created by the Franklin Institute Science Museum, these hotlists contain a prescreened grouping of resources for science educators, students, and enthusiasts. Teacher resources include *The Physical Science Activity Manual* which contains 34 hands-on activities for the classroom. Included are Newtonian Physics for grades 9-12 and activities such as Floating Objects which may be appropriate for grades 5-8. The Project Labs offer student-centered experiments in the areas of general science, physical science, and the natural, biological and environmental sciences.
  Grades K-12; National Science Education Content Standards: Varies according to site visited from the listing.
  `http://sln.fi.edu/tfi/hotlists/physical.html`

- THE PARTICLE ADVENTURE: One of the most popular Web sites for learning the fundamentals of matter and force. Created by the Particle Data Group of Lawrence Berkeley National Laboratory. An award winning, interactive tour of the atom, with visits to quarks, neutrinos, antimatter, extra dimensions, dark matter, accelerators and particle detectors. Simple elegant graphics and translations into eleven languages. May be used by teachers or by students alone or in groups.
  Grades 9-12; National Science Education Content Standards A, B, D
  `http://ParticleAdventure.org`

- PARTICLE PHYSICAL EDUCATION SITES: This rich site maintained by the Particle Data Group provides links to many other educational sites. Organizes the links by subject, level, and type of educational experience.
  Grades 9-12; National Science Education Content Standards: Varies according to site
  `http://pdg.lbl.gov/outreach.html`

- QUARKNET: QuarkNet brings the excitement of particle physics research to high school teachers and their students. Teachers join research groups at sixty universities and labs across the country. These research groups are part of particle physics experiments at CERN, Fermilab, or SLAC. Students learn fundamental physics as they participate in inquiry-oriented investigations and analyze live, online data. QuarkNet is supported in part by the National Science Foundation and the U.S. Department of Energy.
  Grades 9-12; National Science Education Content Standards: A, B, E
  `http://QuarkNet.fnal.gov`

- VIRTUAL VISITOR'S CENTER: This Stanford Linear Accelerator Center Web site explains basic particle physics, linear and synchrotron accelerators, electron gamma showers, cosmic rays, and the experiments conducted at SLAC, including real-world applications. Intended for the general public as well as teachers and students.
  Grades 9-12; National Science Education Content Standards: A, B, D, E, G
  `http://www2.slac.stanford.edu/vvc/Default.htm`

8.3. *Particle Physics Education: Astronomy Lessons and Experiments:*

- HANDS-ON UNIVERSE: Enables students in middle and high schools to investigate the night sky without having to stay out late. Created by a collaboration of teachers and students including the Lawrence Hall of Science at the U.C., Berkeley, it uses high quality astronomical images to explore central concepts in math, science, and technology. Students analyze real images with image processing software similar to that used by professional astronomers. Lesson plans and activities are specifically tied to National Science Education Content Standards A and D, Science as Inquiry, and Earth and Space Science. Schools or districts much purchase the software, teacher and student booklets and materials. PDF color versions of the booklets are available from the Web, as well as a number of lesson plans and materials that do not require the purchased software.
  Grades 5-8 and 9-12; National Science Education Content Standards A, D
  `http://www.handsonuniverse.org`

- WINDOWS TO THE UNIVERSE: Provides a rich array of material for exploring earth and space, physics, geology, and chemistry in K-12 classrooms. Includes numerous, thorough lesson plans on topics ranging from the solar system to atmosphere and weather to physics and chemistry. Student-centered activities such as Building a Magnetometer or Create Your Own Cloud are simple, yet highly engaging. Content standards are detailed for most lesson plans. The People section of this vast but well-organized site traces the history of human scientific inquiry from Archimedes to Stephen Hawking. Three reading levels.
  Grades K-12; National Science Education Content Standards A, B, D, E, G
  `http://www.windows.ucar.edu/`

8.4. *Particle Physics Education: Ask-a-Scientist Sites:*

- ASK THE EXPERTS: Submit questions via a form to scientists at PhysLink.com. Questions are answered free. Beware that they won't answer questions from homework assignments or help design something for a science fair or competition.
  `http://www.physlink.com/Education/AskExperts/Index.cfm`

- HOW THINGS WORK: The author of the popular book, *How Things Work: the Physics of Everyday Life*, has created a site that functions as a virtual 'radio call-in program'. Submit questions about how something works or consult the sixty plus pages of most recent questions which are searchable by date, topic, or keyword.
  `http://howthingswork.virginia.edu/`

- MAD SCIENTIST'S NETWORK: ASK A QUESTION: Scientists at this Web site respond to hundreds of questions a week. Be sure to check out their extensive archive of answered questions and use their Science Fair Links for ideas for projects. Also note questions they decline to answer.
  `http://www.madsci.org/submit.html`

8.5. *Particle Physics Education: Experiments, Demos, & Fun*

- ALL ABOUT LIGHT: From Fermilab, this offers a delightful collection of pages giving classical, relativistic and quantum explanations of light. Advanced placement high school level or above.
  Grades 11-12+
  `http://www.fnal.gov/pub/inquiring/more/light/index.html`

- CANTEACH: PHYSICAL SCIENCE: Canadian elementary teachers have put together a list of investigations and hands-on physics experiments for elementary level. These well-written physical science lesson plans feature such activities as Making a Pinhole Camera, Air Takes Space, Acid and Basic Test, Growing Crystals, Potential and Kinetic Energy, and Evaporation Painting.
  Grades K-4; National Science Education Standards A, B, E
  `http://www.canteach.ca/elementary/physical.html`

- THE EDIBLE/INEDIBLE EXPERIMENTS ARCHIVE: Part of the Mad Scientist's Network, this Web site covers astronomy, mathematics, and physics. Each experiment uses common materials and identifies whether the experiment is edible, inedible, partially drinkable, or not all that edible (!).
  Grades K-8
  `http://www.madsci.org/experiments/`

- HELPING YOUR CHILD LEARN SCIENCE: A wonderful introduction and set of tools for parents of elementary-age children compiled by the U.S. Department of Education. Provides ideas, home experiments, community-based science activities, and more.
  Grades K-4
  `http://www.ed.gov/pubs/parents/Science/index.html`

- INSULTINGLY STUPID MOVIE PHYSICS: An entertaining and educational site to learn how many movie special effects violate the laws of physics. Includes a rating system for movie reviews. Heavy on text, with few graphics. Equations are included. A good way to emphasize, at the high school level, the immutability of the laws of physics in the real world. Provides instructions on how to use movie physics in the classroom and a bibliography.
  Grades 9-12;
  `http://www.intuitor.com/moviephysics`

- PHYSICS-SCIENCE PHYS/SCI DEMOS: This Web site provides over fifty physics demonstrations on the topics of density, motion, force, angular measurement, waves and sound, electricity and magnetism, optics and nuclear physics. Some of the demos feature photographs. Most of the demos are original, although a few were taken from the T.V. program, *Newton's Apple*. The high school teacher who created this site has won both a Presidential Award for Excellence in Mathematics and Science Teaching and the 2003 Classroom Connect Internet Educator of the Year Award.
  Grades to 5-8 and 9-12; National Science Education Content Standards 5-8 and 9-12: A, B, E
  `http://www.darylscience.com/DemoPhys.html`

8.6. *Particle Physics Education: Physics History and Diversity Sites:*

- AIP CENTER FOR HISTORY OF PHYSICS: This site, produced by the American Institute of Physics, aims to preserve and make known the history of modern physics and allied fields including astronomy, geophysics, and optics. Of interest to teachers and students is the Exhibit Hall, with award-winning exhibits including photos and facts about Marie Curie, Einstein, the discovery of the electron, and the invention of the transistor.
  Grades 7-12; National Science Education Content Standard: G
  `http://www.aip.org/history`

- A CENTURY OF PHYSICS: A timeline from the American Physical Society providing a comprehensive history of major physical science developments with a selection of other events from society, art, politics and literature. Provides a physical timeline, an index, a search sytem and reproductions of the posters and images.
  Grades 7-12; National Science Education Content Standard: G
  `http://timeline.aps.org/APS/home_HighRes.html`

- CONTRIBUTIONS OF 20TH CENTURY WOMEN TO PHYSICS: A great resource for that history of science paper, this archive features descriptions of important contributions to science made by 83 women in the 20th century. Provides historical essays and links to additional documentation such as primary source materials.
  Grades 7-12+; National Science Education Content Standard G
  `http://www.physics.ucla.edu/ cwp/`

- EDUCATION AND OUTREACH COMMITTEE ON THE STATUS OF WOMEN IN PHYSICS: Interested in inspiring a young woman to pursue physics? This American Physical Society site features *Physics in Your Future*, which conveys the exciting possibilities of a career in physics to middle and high school girls. Copies of this four-color booklet are available at no charge to students and their parents, educators, guidance counselors, and groups who work with young women. Also available in PDF. The popular, full color, *Celebrate Women in Physics* poster, is also available at no charge.
  Grades 7-12; National Science Education Content Standard G
  `http://www.aps.org/educ/cswp/`
- PHYSLINK.COM HISTORY OF PHYSICS AND ASTRONOMY: This site, which is a compendium of other history of physics, astronomy and science sites, organizes that historical world into: general guides, histories of physics, of astronomy and space exploration, and of mathematics, online archives, museums and exhibits, and famous scientists. Serves as a guide to some of the most well known people and events in the physical sciences.
  Grades 7-12; National Science Education Content Standard: G
  `http://www.physlink.com/Education/History.cfm`
- NOBEL LAUREATES IN PHYSICS 1901-PRESENT: Maintained by SLAC, this site provides very comprehensive information on physics laureates. Links to the Nobel Foundation's pages on each laureate. Also lists the location(s) of the laureate's prize-winning work, where, if appropriate, the laureate is currently working, and where she or he was working when the work was done. Links to books, related Web sites, and to the HEP Database for in-depth bibliography. An interesting Quick Facts section provides great trivia about some of the prize winners.
  Grades 7-12; National Science Education Content Standard: G
  `http://www.slac.stanford.edu/library/nobel/index.html`

8.7. *Particle Physics Education: Art in Physics:*

Note: This modest collection of physics art links is provided for high school art, photography and literature teachers who may be interested in the intersections between science and technology and art and literature, or who wish to take an interdisciplinary approach to the curriculum in collaborating with their science department colleagues.

- DESY IN A SPECIAL LIGHT: Six luminescent pages of particle physics technology photographed at the Deutsches Electronen Synchrotronen Laboratory (DESY) by Peter Ginter, German photographer, in 1997.
  `http://www.peterginter.de/01technology/desy_01.html`
- HIDDEN CATHEDRALS–SCIENCE OR ART?: Part of a secton of the Web site explaining how physicst study particles, this page provides fifteen brilliantly detailed color photographs of the inner workings of particle detectors at the European Organisation for Nuclear Research (CERN) which is the world's largest particle physics center.
  `http://public.web.cern.ch/public/about/how/art/art.html`
- PHYSICS ICONS: Particle physics as delicate, experiential art. The site description says that this is a meditation on the shifting nature of physics iconography. This video clip was featured in the New York P.S.1 exhibit, *Signatures of the Invisible*.
  `http://www-project.slac.stanford.edu/streaming-media/Sub-Movies.html`
- PRESS PHOTO PRIZE FOR CERN: This article describes the photos done by Peter Ginter for CERN. The photos won a third prize from the World Press Photo of the Year competition in 1998.
  `http://bulletin.cern.ch/9911/art4/Text_E.html`
- ESSAYS AND BOOKS ON ART IN PHYSICS AND SCIENCE:
  "Art and Physics–a Beautiful Friendship"
  `http://bulletin.cern.ch/9949/art1/Text_E.html`
  "Art and Physics" by Leonard Shlain
  `http://www.artandphysics.com/h_main.html`
  "Physics Meets Art and Literature"
  `http://physicsweb.org/article/world/15/11/7`
  "Signatures of the Invisible"
  `http://www.ps1.org/cut/press/signatures.html`

9. Software Directories:

- CERNLIB: CERN PROGRAM LIBRARY: A large collection of general purpose libraries and modules offered in both source code and object code forms from the CERN central computing division. Provides programs applicable to a wide range of physics research problems such as general mathematics, data analysis, detectors simulation, data-handling, *etc.* Also includes links to commercial, free, and other software:
  `http://wwwasd.web.cern.ch/wwwasd/index.html`
- FREEHEP: A collection of software and information about software useful in high-energy physics. Searching can be done by title, subject, date acquired, date updated, or by browsing an alphabetical list of all packages:
  `http://www.slac.stanford.edu/find/fhmain.html`
- FERMITOOLS: Fermilab's software tools program provides a repository of Fermilab-developed software packages of value to the HEP community. Permits searching for packages by title or subject category:
  `http://fermitools.fnal.gov/`
- HEPIC: SOFTWARE & TOOLS USED IN HEP RESEARCH: A meta-level site with links to other sites of HEP-related software and computing tools:
  `http://www.hep.net/resources/software.html`
- GRID PHYSICS NETWORK: The GriPhyN Project is developing grid technologies for scientific and engineering projects that collect and analyze distributed, petabyte-scale datasets. Proivdes links to project information such as documents, education, workspace, virtual data toolkits, Chimera and Sphinx, as well as people, activities and news and related projects:
  `http://www.griphyn.org/index.php`
- PARTICLE PHYSICS DATA GRID: The Web site for the U.S. collaboration of federal laboratories and universities to build a worldwide distributed computing model for current and future particle and nuclear physics experiments:
  `http://www.ppdg.net/`

10. Specialized Subject Pages:

10.1. *Subject Pages*

- CAMBRIDGE RELATIVITY: PUBLIC HOME PAGE: These pages focus on the non-technical learner and explain aspects of relativity such as: cosmology, black holes, cosmic strings, inflation, and quantum gravity. Provides links to movies, research-level home pages and to Stephen Hawking's Web site:
  `http://www.damtp.cam.ac.uk/user/gr/public/`
- NEUTRINO WEBSITE: John Bahcall has compiled links to: technical and popular articles, books, the Hubble Space Telescope and other images, models, viewgraphs, cross-section data, software, and more. The place to begin researching neutrinos at a graduate student level and beyond:
  `http://www.sns.ias.edu/~jnb/`

- THE OFFICIAL STRING THEORY WEB SITE: Outstanding compilation of information about string theory includes: basics, mathematics, experiments, cosmology, black holes, people (including interviews with string theorists), history, theater, links to other Web sites and a discussion forum:
  `http://superstringtheory.com/`
- RELATIVITY: BOOKMARKS: Presents over 100 links collected into subject or other logical divisions. Unfortunately, the site owner explains in a note that he has not been able to verify the links for awhile. However, it still represents one of the best initial collections on the subject.:
  `http://physics.syr.edu/research/relativity/RELATIVITY.html`
- RELATIVITY ON THE WORLD WIDE WEB: An excellent set of pages offering links and written information about relativity. Organized into: popular science sites; visualization sites; Web tutorials; observational and experimental evidence and rebuttals; course work (divided into undergraduate and graduate levels); software; research frontiers; and further reading:
  `http://www.math.washington.edu/~hillman/relativity.html`
- SUPERSTRINGS: An online introduction to superstring theory for the advanced student. Includes further links:
  `http://www.sukidog.com/jpierre/strings/`
- THE ULTIMATE NEUTRINO PAGE: This page provides a gateway to an extremely useful compilation of experimental data and results:
  `http://cupp.oulu.fi/neutrino/`