

# New Ways to Access PDG Data

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For the PDG Collaboration

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# PDG and the *Review of Particle Physics*



- The Particle Data Group (PDG) provides a comprehensive summary of particle physics and related areas from cosmology and astrophysics in a single publication, the *Review of Particle Physics* 
  - International collaboration of 240 scientists, 173 institutions, 25 countries
  - Berkeley Lab provides scientific leadership, central coordination, and technical expertise & infrastructure
  - Funded primarily by the DOE Office of High Energy Physics with important contributions from MEXT (Japan), INFN, and CERN
- The Review of Particle Physics consists of
  - Summary Tables
  - Particle Listings
  - **120 individual review articles**, covering a wider range of topics
  - Available online at <u>pdg.lbl.gov</u> and <u>pdgLive.lbl.gov</u>, as well as in print (PDG Book and Booklet), as an Android/web app, and downloadable files
- Journal publication every 2 years (updated online every year)
  - This year's journal publication to appear in Phys. Rev. D
  - 2,400 pages

|  |  | 2024 edition and new PDG  | AP1 available   |  |           |
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|  | The Revie<br>S. Navas et al. (Pa   | ew of Particl   | e Physics   | <b>(2024)</b><br>01 (2024)   |           |
|  | pdgLive - Interactive I  | istings   | Order PI  | DG Products  |           |
|  | Summary Table  | s   | Topic   | al Index +   |           |
|  | Reviews, Tables, P   | lots  | Downlo  | ads & API +  |           |
|  | Particle Listings  |   | Prev. Editions (  | & Errata) 1957-2023  |           |
|  | Errata   |   | PDG   | Outreach   |           |
|  | Results pravided by Gooole   | ٩   | Non-PDC   | Resources +  |           |
|  |  |   | 2024 edition and new  | <u>r PDG APi</u> available   |           |
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| Courge<br>grant<br>grant<br>W<br>W<br>W<br>W<br>Mean<br>Ason<br>Strang<br>Charn<br>Botton<br>Botton<br>Botton<br>Botton  | A Higgs Bosons      A Higgs Bosons      If Hig                            | Phe Review of F           3. Stars of Darket Cata Course           a partons           a           a           b           a           a           a           a           a           b           a           b           b           b           c           φ           τ           b           b           b           c           φ           φ           φ           a           b           b           b           b           c           a           b           b           b           b           b           b           b           b           b           b           b           c           c           c           c           c           c           c           c  | PDC HOME SI<br>Particle Phys<br>to the additional or Phys Res 0<br>(Free of the second<br>Processor   | NORTOUTS CITATION CONT<br>iCs (2024)<br>Coord (2024)<br>Coords<br>Light quarks (e. d. a)<br>Š<br>ž<br>Prequark<br>Cher Searches<br>Magnetic Montepole<br>Supersymmetry Particles<br>Guard and Lepton Compositements<br>Earth Dimensionel<br>Supersymmetry Samples  |           |
| Courgen<br>7 ghonn<br>8 min the<br>2<br>11 Neutr<br>Charge<br>Assen<br>9<br>Menon<br>9<br>Charge<br>8<br>Charge<br>8<br>Charge<br>8<br>Charge<br>8<br>Charge<br>8<br>Charge<br>1<br>Heavy<br>8<br>Charge<br>1<br>Heavy<br>8<br>Charge<br>1<br>Heavy<br>8<br>Charge<br>1<br>Heavy<br>8<br>Charge<br>1<br>Heavy<br>8<br>Charge<br>1<br>Heavy<br>8<br>Charge<br>1<br>Heavy<br>8<br>Charge<br>1<br>Heavy<br>8<br>Charge<br>1<br>Heavy<br>8<br>Charge<br>1<br>Heavy<br>8<br>Charge<br>1<br>Heavy<br>8<br>Charge<br>1<br>Heavy<br>8<br>Charge<br>1<br>Heavy<br>8<br>Charge<br>1<br>Heavy<br>8<br>Charge<br>1<br>Heavy<br>8<br>Charge<br>1<br>Heavy<br>8<br>Charge<br>1<br>Heavy<br>8<br>Charge<br>1<br>Heavy<br>8<br>Charge<br>1<br>Heavy<br>8<br>Charge<br>1<br>Heavy<br>8<br>Charge<br>1<br>Heavy<br>8<br>Charge<br>1<br>Heavy<br>8<br>Charge<br>1<br>Heavy<br>8<br>Charge<br>1<br>Heavy<br>8<br>Charge<br>1<br>Heavy<br>8<br>Charge<br>1<br>Heavy<br>8<br>Charge<br>1<br>Heavy<br>8<br>Charge<br>1<br>Heavy<br>8<br>Charge<br>1<br>Heavy<br>8<br>Charge<br>1<br>Heavy<br>8<br>Charge<br>1<br>Heavy<br>8<br>Charge<br>1<br>Heavy<br>8<br>Charge<br>1<br>Heavy<br>8<br>Charge<br>1<br>Heavy<br>8<br>Charge<br>1<br>Heavy<br>8<br>Charge<br>1<br>Heavy<br>8<br>Charge<br>1<br>Heavy<br>8<br>Charge<br>1<br>Heavy<br>8<br>Charge<br>1<br>Heavy<br>8<br>Charge<br>1<br>Heavy<br>8<br>Charge<br>1<br>Heavy<br>8<br>Charge<br>1<br>Heavy<br>8<br>Charge<br>1<br>Heavy<br>8<br>Charge<br>1<br>Heavy<br>8<br>Charge<br>1<br>Heavy<br>8<br>Charge<br>1<br>Heavy<br>8<br>Charge<br>1<br>Heavy<br>8<br>Charge<br>1<br>Heavy<br>8<br>Charge<br>1<br>Heavy<br>8<br>C<br>Charge<br>1<br>Heavy<br>8<br>Charge<br>1<br>Heavy<br>8<br>C<br>Charge<br>1<br>Heavy<br>8<br>Charge<br>1<br>Heavy<br>8<br>Charge<br>1<br>He<br>1<br>Heavy<br>8<br>C<br>Charge<br>1<br>Heavy<br>8<br>Charge<br>1<br>Heavy<br>8<br>Charge<br>1<br>Heavy<br>8<br>Charge<br>1<br>Heavy<br>8<br>Charge<br>1<br>Heavy<br>8<br>Charge<br>1<br>Heavy<br>8<br>Charge<br>1<br>Heavy<br>8<br>Charge<br>1<br>Heavy<br>8<br>C<br>H<br>H<br>H<br>H<br>H<br>H<br>H<br>H<br>H<br>H<br>H<br>H<br>H<br>H<br>H<br>H<br>H<br>H   | A Higgs Bosons   A Higgs Bosons   A Higgs Bosons   A Higgs Bosons (H <sup>1</sup> , H <sup>1+1</sup> )  A Missons  A Miss | Cherence         Control           2         Name of University how Concerns           2         Lapons           2         Analysis           4         Analysis           4         Analysis           4         Analysis           4         Baryons           4         Baryons           5         Baryons           6         Baryons           7         Baryons           8         Baryons           9         Baryons   | PDC HOME SI<br>Particle Phys<br>to be deddied or Pyr ter 01   | NORTCUTS CITATION CONT<br>iCS (2024)<br>ID: Coord (2024)<br>Coords<br>Lgft quarks (u, d, a)<br>Š<br>Free quark<br>Magnetic Monopole<br>Magnetic Monopole<br>Supersymmetric Pattales<br>Free quark<br>Coher Socrobes<br>Magnetic Monopole<br>Coher Socrobes<br>Magnetic Monopole<br>Coher Socrobes<br>Magnetic Monopole<br>Coher Socrobes<br>Magnetic Monopole<br>Coher Socrobes<br>Magnetic Monopole<br>Coher Socrobes<br>Coher Socrobes   |           |



# Summary Tables and Particle Listings



### **Summary Tables**

- PDG world averages (or best limits)
- Masses, widths/lifetimes, branching fractions, ...

#### $I(J^P) = \frac{1}{2}(1^-)$ D\*(2007)0 Mass $m = 2006.85 \pm 0.05$ MeV (S = 1.1) $m_{D^{*0}} - m_{D^0} = 142.014 \pm 0.030 \text{ MeV} \quad (S = 1.5)$ Full width $\Gamma$ < 2.1 MeV, CL = 90% $\overline{D}^*(2007)^0$ modes are charge conjugates of modes below. $D^*(2007)^0$ DECAY MODES Fraction $(\Gamma_i/\Gamma)$ Confidence level (MeV/c) $D^{0}\pi^{0}$ (64.7 ±0.9)% 43 $D^0 \gamma$ $(35.3 \pm 0.9)\%$ 137 $D^{0}e^{+}e^{-}$ $(3.91\pm0.33)\times10^{-3}$ 137 $\mu^+\mu^ \times 10^{-8}$ < 2.5 90% 998 $e^+e^ \times 10^{-6}$ < 1.7 90% 1003

### **Particle Listings**

- Detailed information on how PDG arrived at any given average
- Curated and annotated lists of relevant published results

#### $m_{D^*(2007)^0} - m_{D^0}$

|   |   | - () -  |   |  |
|---|---|---|---|--|
| The fit incl<br>and <i>D<sub>s1</sub>(2</i> | udes D <sup>±</sup> , D <sup>0</sup> ,<br>536) <sup>±</sup> mass ar | $D_s^{\pm}$ , $D^{*\pm}$ , $D^{*0}$ , $D_s^{*\pm}$ nd mass difference mea | , <i>D</i> <sub>1</sub> (2420<br>surement | 0) <sup>0</sup> , <i>D</i> <sup>*</sup> <sub>2</sub> (2460) <sup>0</sup> ,<br>s. |
| VALUE (MeV)                                 | EVTS  | DOCUMENT ID   | TECN                                      | COMMENT  |
| 142.014±0.030 OU                            | R FIT Error i   | includes scale factor of  | 1.5.                                      |  |
| 142.016±0.030 OU                            | R AVERAGE   | Error includes scale fa   | ctor of 1.                                | 5.   |
| $142.007 \pm 0.015 \pm 0.015$               | 014 10k   | <sup>1</sup> TOMARADZE 15   | CLEO                                      | $e^+e^-  ightarrow  { m hadrons}$  |
| 142.2 ±0.3 ±0.                              | 2 145   | ALBRECHT 95F  | ARG                                       | $e^+ e^-  ightarrow  { m hadrons}$   |
| 142.12 $\pm 0.05 \pm 0.05$                  | 05 1176   | BORTOLETTO92B   | CLE2                                      | $e^+e^-  ightarrow  { m hadrons}$  |
| • • • We do not us                          | se the following  | data for averages, fits   | , limits, e                               | etc. • • •   |
| 142.2 ±2.0                                  |   | SADROZINSKI 80  | CBAL                                      | $D^{*0} \rightarrow D^0 \pi^0$   |
| 142.7 ±1.7                                  |   | <sup>2</sup> GOLDHABER 77   | MRK1                                      | e <sup>+</sup> e <sup>-</sup>  |
| <sup>1</sup> Obtained by ana                | alyzing CLEO-c  | data but not authored   | by the C                                  | LEO Collaboration . This   |
| value comes fro                             | m the average   | of the results for two  | decay mo                                  | des, $D^0 \rightarrow K^- \pi^+$ and   |
| $D^0 \rightarrow K^- \pi^+$                 | $\pi^{-}\pi^{+}$ .  |   |   | ,  |
| <sup>2</sup> From simultane                 | ous fit to $D^*(2)$   | $(010)^+$ $D^*(2007)^0$ D   | + and $I$                                 | 0  |



# 120 Review Articles



### **Covering wide range of topics, including**

- Constants, units, atomic & nuclear properties
- Standard Model and related topics
- Astrophysics and cosmology
- Experimental methods and colliders
- Mathematical tools
- Kinematics, cross-section formulae and plots
- Particle properties
- Hypothetical particles and concepts

### 582 34. Passage of Particles Through Matter"

As shown in Fig. 34.11, stopping powers for  $e^-,e^+,$  and heavy particles are not dramatically different. In silicon, the minimum value for electrons is 1.50 MeV cm<sup>2</sup>/g (at  $\gamma=3.3$ ); for positrons, 1.46 MeV cm<sup>2</sup>/g (at  $\gamma=3.7$ ), and for muons, 1.66 MeV cm<sup>2</sup>/g (at  $\gamma=3.58$ ).

#### 34.4.2 Radiation length

High-energy electrons predominantly lose energy in matter by bremstrahlung, and high-energy photons by  $e^+e^-$  pair production. The characteristic amount of matter traversed for these related interactions is called the radiation length  $X_0$ , usually measured in g cm<sup>-2</sup>. It is the mean distance over which a high-energy electron loses all but 1/e of its energy by bremstrahlung. It is also the appropriate scale length for describing high-energy electromagnetic cascades.  $X_0$  has been calculated and tabulated by Y.S. Tsai [42]:

$$\frac{1}{X_0} = 4\alpha r_e^2 \frac{N_A}{A} \left\{ Z^2 \left[ L_{rad} - f(Z) \right] + Z L'_{rad} \right\}. \quad (34.25)$$

For A = 1 g mol<sup>-1</sup>,  $4\alpha r_e^2 N_A/A = (716.408 \text{ g cm}^{-2})^{-1}$ .  $L_{\text{rad}}$ and  $L'_{\text{rad}}$  are given in Table 34.2. The function f(Z) is an infinite sum, but for elements up to uranium can be represented to 4-place accuracy by

$$f(Z) = a^2 \left[ (1 + a^2)^{-1} + 0.20206 \\ - 0.0369 a^2 + 0.0083 a^4 - 0.002 a^6 \right], \qquad (34.1)$$

where  $a = \alpha Z$  [43].

Table 34.2: Tsai's  $L_{\rm rad}$  and  $L'_{\rm rad}$ , for use in calculating the radiation length in an element using Eq. (34.25).

| Element | Z  | $L_{\rm rad}$          | $L'_{\rm rad}$       |
|---------|----|------------------------|----------------------|
| Н       | 1  | 5.31                   | 6.144                |
| He      | 2  | 4.79                   | 5.621                |
| Li      | 3  | 4.74                   | 5.805                |
| Be      | 4  | 4.71                   | 5.924                |
| Others  | >4 | $\ln(184.15 Z^{-1/3})$ | $\ln(1194 Z^{-2/3})$ |

The radiation length in a mixture or compound may be approximated by

 $1/X_0 = \sum$ 

$$w_j/X_j$$
, (34.2)

where  $w_j$  and  $X_j$  are the fraction by weight and the radiation length for the *j*th element.

#### 34.4.3 Bremsstrahlung energy loss by $e^{\pm}$

At vory high energies and excent at the high-energy tin of the



Figure 34.11: Fractional energy loss per radiation length in lead as a function of electron or positron energy. Electron (positron) scattering is considered as ionization when the energy loss per collision is below 0.255 MeV, and as Møller (Bhabha) scattering when it is above. Adapted from Fig. 3.2 from Messel and Craw ford, Electron-Photon Shouer Distribution Function Tables for Lead, Copper, and Air Absorbers, Pergamon Press, 1970. Messel and Crawford use  $X_0(Pb) = 5.82$  g/cm<sup>2</sup>, but we have modified the figures to reflect the value given in the Table of Atomic and Nuclear Properties of Materials ( $X_0(Pb) = 6.37$  g/cm<sup>2</sup>).



**Figure 34.12:** The normalized bremsstrahlung cross section  $k \, d\sigma_{LPM}/dk$  in lead versus the fractional photon energy y = k/E. The vertical axis has units of photons per radiation length.

nearby scattering centers (the LPM effect) [44, 45] and dielectric suppression [46, 47]. These and other suppression effects in bulk media are discussed in Sec. 34.4.6.

With decreasing energy ( $E \lesssim 10$  GeV) the high-y cross section drops and the curves become rounded as  $y \to 1$ . Curves of this familar shape can be seen in Rossi [2] (Figs. 2.11.2,3); see also the minim by  $Cext \in M$ , M = 0.



# Distribution of the *Review of Particle Physics*



|         | (The  | antipar   | Masses and mean in<br>ticles are assumed to have   | es of elementary parts the same spins, m | articles; November, 1957<br>masses, and mean lives as the   | particles listed)   |
|---------|---|---|--|--|---|---|
|         | Particle  | Spin  | Mass<br>(Errors represent<br>standard deviation)<br>(Mev)  | Mass<br>difference<br>(Mev)              | Mean life<br>(sec)  | Decay rate<br>(number<br>per<br>second)   |
| hoton   | Y   | 1   | 0  |  | stable  | 0   |
| Lepton  | -   | 1<br>1<br>1   | 0<br>0.510976 (m)<br>105.70 ±0.06 (m)  |  | stable<br>stable<br>(2.22 ±0.02) ×10 <sup>-6</sup>  | 0<br>0<br>0.45 × 10 <sup>6</sup>  |
|         | **<br>**<br>**  | 0<br>0<br>0   | $\begin{array}{c} 139.63 \pm 0.06 \ \text{(a)} \\ 135.04 \ a 0.16 \ \text{(a)} \\ 494.0 \ a 0.2 \ \text{(g)} \\ 494.4 \ a 1.8 \ \text{(i)} \end{array}$  | 4.6 (m)<br>0.4 ml .8 H                   | $\begin{array}{cccc} \{ \&, 56 & a & 0.05 \} \times 10^{-8} & (a) \\ < 4 & \times 10^{-16} & (d) \\ (1.224a0.013) \times 70^{-8} & (b) \\ \vdots & (0.95 & a0.08) \times 10^{-10} & (c) \\ \vdots & (4 < \tau < 13) & \times 10^{-8} & (c) \end{array}$ | 0.39 × 10 <sup>8</sup><br>> 2.5 × 10 <sup>15</sup><br>0.815 × 10 <sup>8</sup><br>1.05 × 10 <sup>10</sup><br>(0.07< r<0.25)×10 |
| Baryone | P<br>A<br>Z <sup>+</sup><br>Z <sup>-</sup><br>Z <sup>0</sup><br>X | 1<br>1<br>1<br>1<br>1<br>1<br>1<br>1<br>1<br>1<br>1<br>1<br>1<br>1<br>1<br>1<br>1<br>1<br>1 | $\begin{array}{c} 938,213 \pm 0,01  (a) \\ 939,506 \pm 0,01  (a) \\ 1115,2  \pm 0,14  (j) \\ 1189,4  \pm 0,25  (i) \\ 1199,5  \pm 0,5  (a) \\ 1190,5  -1,4  (p) \\ 1320,4  \pm 2,2  (q) \end{array}$ | 7.1 ± 0.4<br>6.0 <sup>+1.4</sup>         |   | 0.0<br>0.96 ×10-3<br>0.36 ×1010<br>1.21 ×1010<br>0.66 ×1010<br>>10 ×1010<br>theoretically -10<br>(>0.005, €0.2) ×101          |





New Ways to Access PDG Data, ICHEP 2024





# To make PDG data available in machine-readable format, PDG has been developing a new API with three related tools, aimed at different use cases

- REST API
  - Download data shown by pdgLive in JSON format
  - Can also be used in scripts/programs w/o installing any PDG-specific software
  - Intended for incidental, rate-limited use

### Python API

- High-level API for accessing PDG data
- Includes local data store (SQLite database file)
- Database files
  - SQLite files with part of or whole PDG dataset
  - Low-level access for software developers

### Status

- First production release with 2024 online publication (beta version since June 2023)
- Access to PDG world averages and limits (including branching fractions)
- Access to measurements from Particle Listings coming soon
- All tools will be updated with each new edition of the *Review* of *Particle Physics*



# **REST API - Get Data in JSON Format**







# Python API



### Implemented in Python package pdg

- Installation: pip install pdg
- Supports Python 3 (and for now also 2.7)
- github.com/particledatagroup/api

### Documentation at <a href="mailto:pdgapi.lbl.gov">pdgapi.lbl.gov</a>

| 🏶 PDG API  |
|--|
| Search docs  |
|  |
| CONTENTS:  |
| Overview   |
| PDG Identifiers  |
| REST API   |
| Python API   |
| Requirements   |
| Installation   |
| 🗄 Usage  |
| Examples   |
| Particle Monte Carlo number, mass and<br>quantum numbers |
| Branching fractions                                      |
| Decays   |
| Particle properties (except branching<br>fractions)      |
| Detailed software documentation                          |
| License  |
| PDG database file  |
| Development status                                       |

| * | Python API |  |
|---|------------|--|

#### **Python API**

The PDG Python API provides a high-level tool for programmatically accessing PDG data. For most users, this is the recommended way to access PDG data in machine-readable format. The Python API provides straightforward navigation from particles to their properties and the corresponding information included in the *Review of Particle Physics*. After the initial installation, the Python API does not require an Internet connection.

The Python API is implemented in Python package pdg and uses a PDG database file as its default data repository. The database file corresponding to the current edition of the *Review of Particle Physics* at the time of releasing a given version of the package is installed together with the package. When the *Review of Particle Physics* is updated, a new version of the <u>indeg</u> package with the latest data is released.

To access the data from other editions, additional database files can be downloaded from the PDG website and used with the Python API. Since SQLAIchemy is used for all database access, the necessary database tables could be copied from the SQLite database file into an existing database system (as long as it is supported by SQLAIchemy), and the Python API could then be used with that database system.

The pdg package is released as open source software and can be found at github.com/ particledatagroup/api.

| Code  O Issues  Pull requests  | 🛈 Security 🗠 Insights                                 | L Noti       | fications 및 Fork 2 ☆ Star 1:  |  |  |
|--|---|--------------|---|--|--|
| १९ main ▼ 북 5 Branches 🛇 6 Tags  | Q Go to file  | <> Code •    | About   |  |  |
| liter in the second sec | om particledatagroup/dev 🚥 ed22911 · 5 days ago       | 118 Commits  | API for programmatic access to<br>data  |  |  |
| docs   | Update CHANGELOG for version 0.1.2                    | 5 days ago   | 🖽 Readme  |  |  |
| 🖿 pdg  | Update SQLite file to fix is_limit bug and update pdg | 5 days ago   | কা View license   |  |  |
| tests  | Switch development version to 0.1.2                   | 2 weeks ago  | <ul> <li>Custom properties</li> <li>☆ 12 stars</li> <li>③ 3 watching</li> </ul> |  |  |
| 🗋 .gitattributes   | Initial commit  | last year    |   |  |  |
| 🗅 .gitignore   | Copy my current dev version from the PDG SVN rep      | last year    | v     2 forks       Report repository   |  |  |
| CHANGELOG.md   | Update CHANGELOG for version 0.1.2                    | 5 days ago   |   |  |  |
| CONTRIBUTING.md  | Final documentation updates for version 0.1.0         | 2 months ago | Releases  |  |  |
| COPYRIGHT.txt  | Copy my current dev version from the PDG SVN rep      | last year    | 🛇 6 tags  |  |  |
| LICENSE.txt  | Copy my current dev version from the PDG SVN rep      | last year    | Daskages  |  |  |
| MANIFEST.in  | Copy my current dev version from the PDG SVN rep      | last year    | No packages published   |  |  |
| C README.md  | Final documentation updates for version 0.1.0         | 2 months ago |   |  |  |
| 🗅 setup.py   | Switch development version to 0.1.2                   | 2 weeks ago  | Contributors 2  |  |  |
| 🗅 tox.ini  | Copy my current dev version from the PDG SVN rep      | last year    | juergberinger Juerg Beringer  |  |  |

#### PDG Python API

The Python package pag provides programmatic access to the data published by the Particle Data Group (PDG) in the Review of Particle Physics. The Review of Particle Physics is available online from the PDG website at <a href="https://pdg.lbl.qov">https://pdg.lbl.qov</a>. General information about PDG and the Review of Particle Physics can be found at <a href="https://pdg.lbl.qov">https://pdg.lbl.qov</a>. General information about PDG and the Review of Particle Physics can be found at <a href="https://pdg.lbl.qov">https://pdg.lbl.qov</a>. General information about PDG and the Review of Particle Physics can be found at <a href="https://pdg.lbl.qov">https://pdg.lbl.qov</a>. General information about PDG and the Review of Particle Physics can be found at <a href="https://pdg.lbl.qov">https://pdg.lbl.qov</a>. General information about PDG and the Review of Particle Physics can be found at <a href="https://pdg.lbl.qov">https://pdg.lbl.qov</a>. General information about PDG and the Review of Particle Physics can be found at <a href="https://pdg.lbl.qov">https://pdg.lbl.qov</a>. General information about PDG and the Review of Particle Physics can be found at <a href="https://pdg.lbl.qov">https://pdg.lbl.qov</a>. General information about PDG and the Review of Particle Physics can be found at <a href="https://pdg.lbl.qov">https://pdg.lbl.qov</a>. General information about PDG and the Review of Particle Physics can be found at <a href="https://pdg.lbl.qov">https://pdg.lbl.qov</a>. General information about PDG and the Review of Particle Physics information about PDG and the Review of Particle Physics information".

#### Documentation is available at https://pdgapi.lbl.gov/doc.

The source code for this package can be found at <u>https://github.com/particledatagroup/ap</u>. This repository uses Git LFS to manage SQlite database files. You need to have Git LFS installed before checking out the repository with git. Please see the instructions at <u>https://github.com/gitls?git.lfs</u>.

#### • Python 100.0%

New Ways to Access PDG Data, ICHEP 2024

#### LAWRENCE BERKELEY NATIONAL LABORATORY

#### luerg Beringer (LBNL), page 8



# Using the Python API



| <pre>import pdg api = pdg.connect() print(api)</pre>   |  |   | Import package, connect to<br>the default database, and<br>show what we're using   |
|--|--|---|--|
| 2024 Review of Particle Physic<br>S. Navas et al. (Particle Data<br>(C) Particle Data Group (PDG),<br>For further information see ht                           | s, data release 2024-05-31 02:<br>Group), Phys. Rev. D 110, 030<br>data released under CC BY 4.0<br>tps://pdg.lbl.gov/api  | 00:13 PDT, API version 0.1<br>0001 (2024)<br>)  | .2   |
| <pre>dstar0 = api.get_particle_by_mcid(423) # dstar0 = api.get_particle_by_name('D^*(2007)0') # api.get('M061')[0] Get particle data in one several ways</pre> |  |   |  |
| dstar0.description, dstar0.mci   | d, dstar0.mass, dstar0.is_meso   | n, dstar0.quantum_I   | Get some particle properties   |
| ('D^*(2007)0', 423, 2.00685250   | 2141979, True, '1/2')  |   |  |
| <pre>for bf in dstar0.branching_fra     print(f'{bf.description:30</pre>   | ctions():<br>}', bf.display_value_text)  |   | Iterate over and print all branching fractions   |
| D^*(2007)0> D0 pi0<br>D^*(2007)0> D0 gamma<br>D^*(2007)0> D0 e+ e-<br>D^*(2007)0> mu+ mu-<br>D^*(2007)0> e+ e-   | (64.7+-0.9)%<br>(35.3+-0.9)%<br>(3.91+-0.33)E-3<br><2.5E-8<br><1.7E-6  | See <u>documentation</u><br>features and ex   | n for more<br>amples   |
|  | <pre>import pdg<br/>api = pdg.connect()<br/>print(api)<br/>2024 Review of Particle Physic<br/>S. Navas et al. (Particle Data<br/>(C) Particle Data Group (PDG),<br/>For further information see ht<br/>dstar0 = api.get_particle_by_m<br/># dstar0 = api.get_particle_by_m<br/>('D^*(2007)0 -&gt; D0 gamma<br/>D^*(2007)0&gt; D0 pi0<br/>D^*(2007)0&gt; D0 et e=<br/>D^*(2007)0&gt; D0 et e=<br/>D^*(2007)0&gt; et e=</pre> | <pre>import pdg<br/>api = pdg.connect()<br/>print(api)<br/>2024 Review of Particle Physics, data release 2024-05-31 02:<br/>S. Navas et al. (Particle Data Group), Phys. Rev. D 110, 036<br/>(C) Particle Data Group (PDG), data released under CC BY 4.6<br/>For further information see https://pdg.lbl.gov/api<br/>dstar0 = api.get_particle_by_mcid(423)<br/># dstar0 = api.get_particle_by_name('D^*(2007)0')<br/># api.get('M061')[0]<br/>dstar0.description, dstar0.mcid, dstar0.mass, dstar0.is_meso<br/>('D^*(2007)0', 423, 2.006852502141979, True, '1/2')<br/>for bf in dstar0.branching_fractions():<br/>print(f'{bf.description:30}', bf.display_value_text)<br/>D^*(2007)0&gt; D0 pi0 (64.7+-0.9)%<br/>D^*(2007)0&gt; D0 gamma (35.3+-0.9)%<br/>D^*(2007)0&gt; D0 et e- (3.91+-0.33)E-3<br/>D^*(2007)0&gt; mut mu- &lt;2.5E-8<br/>D^*(2007)0&gt; et e- &lt;1.7E-6</pre> | <pre>import pdg<br/>api = pdg.connect()<br/>print(api)<br/>2024 Review of Particle Physics, data release 2024-05-31 02:00:13 PDT, API version 0.1<br/>S. Navas et al. (Particle Data Group), Phys. Rev. D 110, 030001 (2024)<br/>(C) Particle Data Group (PDG), data released under CC BY 4.0<br/>For further information see https://pdg.lbl.gov/api<br/>dstar0 = api.get_particle_by_mcid(423)<br/># dstar0 = api.get_particle_by_name('D^*(2007)0')<br/># api.get('M061')[0]<br/>dstar0.description, dstar0.mcid, dstar0.mass, dstar0.is_meson, dstar0.quantum_I<br/>('D^*(2007)0', 423, 2.006852502141979, True, '1/2')<br/>for bf in dstar0.branching_fractions():<br/>print(f'{bf.description:30}', bf.display_value_text)<br/>D^*(2007)0&gt; D0 pi0 (64.7+-0.9)%<br/>D^*(2007)0&gt; D0 pet e- (3.91+-0.33)E-3<br/>D^*(2007)0&gt; D0 et e- (1.7E-6</pre> |



# Making a PDG History Plot in Python







# Searching the *Review of Particle Physics*



### **Current search (using Google):**



### Can we do better with recent AI tools?

- Paragraph-level results and preview
- Fine-grained references
  - Link to specific page in review's PDF file, rather than to whole file
- Get values from Summary Tables
  - "Value of B0 mass?"
- Summarize information
  - "How is the top quark mass measured?"

•





### • Use Large Language Model (LLM) to determine what user asks for

- Specific value of a quantity? Figure or table from a review?
- General question about a topic covered in PDG review?

### • For PDG reviews ("semantic search")

- Split review into small chunks (paragraph or smaller) while keeping association to pages in the PDF file
- Using embedding model and vector database, represent each chunk and user's query in a high-dimensional vector space
- Retrieve relevant chunks based on a similarity score

### • For data from Summary Tables or Listings

- Use a LLM to determine what quantity (PDG ID) user asks for
- Then retrieve that data using new PDG API

### • If user wants, use LLM to summarize search results

- Only information from PDG is used in the summary
- Retrieval Augmented Generation (RAG)

### Must avoid hallucinations

- Text found via search comes verbatim from PDG review articles
- Values are from Summary Tables and Particle Listings, retrieved via PDG API
- Summaries based only on text and values from PDG (RAG)





- PDG reviews authored in LaTeX with PDG-specific LaTeX style file, distributed as PDF files
- How to convert to more suitable, structured format such as Markdown (or HTML)?
  - From LaTeX sources (preferred), but so far not successful with standard tools (pandoc, LaTeXML)
  - From PDF files several powerful tools have recently become available
    - <u>Nougat: Neural Optical Understanding for Academic Documents (arXiv:2308.13418)</u> mostly succeeds with excellent accuracy, but correctness is not guaranteed and there are occasional mistakes
- Math support in Markdown dependent on Markdown flavor
  - <u>mathpix-markdown-it</u> adds advanced equation and table support via LaTeX syntax, used by Nougat
- Some other tools
  - Custom code for semantic chunking
  - PDFFigures 2.0 to extract figures
  - Embedding model (e.g. <u>bge-base-en-v1.5</u> with 768 embedding dimensions)
  - <u>Chroma</u> vector database
  - Langchain
  - A LLM (e.g. GPT-40)



Parti

<u>61. T</u>

# A First Prototype



| e data group  | AI S  | Search  | Ass   | Version: n   | gbase-bgebase (RPP 2024)  | 91. Searches for Quark and Lepton Compositeness, page 5       (TEXT, chunk 9)       Score = 0.765         From section 91.1 Limits on contact peractions:   |
|---|---|---|---|--|---------------------------|---|
| SMEFT operators<br>op Quark, page 3 (TA<br>rom section Couplings: | BLE, chunk 12)<br>Operator Field coo<br>$O^{1(ijk)}$ $(q, \gamma^{\mu}q)$   | ontent 0<br>our-quark   | Operator  | Field content<br>Two-quark-two-lepton<br>( $I_{c} \alpha^{\mu} L ) (\bar{\alpha}, \alpha^{\mu} m)$   | Search Summarize          | Eq. (91.1) can also be regarded is a part of more general dimension-six operators in the context of low-energy standard-model effective field theory (SMEFT). For a complete list of SM gauge-invariant dimension-six operators, see [30, 31]. A computation of the one-loop is that the set of SM gauge-invariant dimension-six operators, see [30, 31]. A computation of the one-loop is (35, 36, 37] for recent reviews. Ref. [17] or k, using the CMS data of the inclusive jet that the set of |
|   | $O_{qq}^{3(ijkl)} = (\bar{q}_i \gamma^{\mu} \tau^I q)$ $O_{qu}^{3(ijkl)} = (\bar{q}_i \gamma^{\mu} \tau^I q)$ $O_{qu}^{1(ijkl)} = (\bar{q}_i \gamma^{\mu} q)$ $O_{qu}^{8(ijkl)} = (\bar{q}_i \gamma^{\mu} \tau^I q)$  | $\begin{aligned} &(q_j)(\bar{q}_k\gamma_\mu \tau^I q_l) \\ &(\bar{u}_k\gamma_\mu u_l) \\ &(\bar{u}_k\gamma_\mu u_l) \end{aligned} \qquad $   | $O_{lq}^{3(ijkl)}$<br>$O_{lq}^{(ijkl)}$<br>$O_{lq}^{(ijkl)}$  | $(\bar{l}_{i}\gamma^{\mu}\tau^{l}l_{j})(\bar{q}_{k}\gamma^{\mu}\tau^{l}q_{l})$ $(\bar{l}_{i}\gamma^{\mu}l_{j})(\bar{q}_{k}\chi^{\mu}u_{l})$ $(\bar{l}_{i}\gamma^{\mu}l_{j})(\bar{u}_{k}\gamma^{\mu}u_{l})$   |                           | 61. Top Quark, page 4     (TEXT, chunk 15)     Score = 0.749       From section Couplinas:     4  |
|   | $\begin{array}{llllllllllllllllllllllllllllllllllll$  | $\begin{array}{l} (g_{J})(\forall s, \mu) \stackrel{\text{def}}{=} \langle \mathbf{d}_{l} \rangle \\ (d_{k}\gamma_{\mu}d_{l}) \stackrel{\text{def}}{=} \langle \mathbf{d}_{k}\gamma_{\mu}T^{k}d_{l} \rangle \\ (\tilde{a}_{k}\gamma_{\mu}d_{l}) \stackrel{\text{def}}{=} \langle \mathbf{d}_{k}\gamma_{\mu}T^{k}d_{l} \rangle \\ (\tilde{a}_{k}\gamma_{\mu}d_{l}) \stackrel{\text{def}}{=} \langle \mathbf{d}_{k}d_{l} \rangle \\ (z_{k}d_{l}) \stackrel{\text{def}}{=} \langle \mathbf{d}_{k}T^{k}d_{l} \rangle \end{array}$   | $O_{eq}^{(ijkl)}$<br>$O_{eu}^{(ijkl)}$<br>$O_{lequ}^{1(ijkl)}$<br>$O_{lequ}^{3(ijkl)}$<br>$O_{lequ}^{(ijkl)}$ | $\begin{bmatrix} (e_{i}, \gamma^{\mu}e_{j})(\hat{u}_{k}, \gamma^{\mu}u_{l}) \\ (l \\ for advance) \end{bmatrix}$   | tent, even<br>d math      | The definitions of the SMEFT operators can be organised in four categories: Four-quark-two-lepton, and baryon-lepton-number violating operators. The overwhelming number of four-fermion operators is tamed by adopting simplifying assumptions about beyond be, standard-model flavor structures. A baseline flavor scenario in the quark sector and motivated by the minimal flavor structures. A baseline flavor scenario in the quark sector and motivated by the minimal flavor structures. A baseline flavor scenario in the quark sector and motivated by the minimal flavor structures. A baseline flavor scenario in the quark sector and motivated by the minimal flavor structures. A baseline flavor scenario in the quark sector and motivated by the minimal flavor structures. In this of degrees of freedom are produced for the operators of each category of field content:   |
|   | Two-qu $\ddagger O_{uv}^{(ij)}$ $\bar{q}_i u_j \rho$ ( $\varphi$ $\bar{d}_{pq}$ $O_{vq}^{(ij)}$ $(\phi^{\dagger} \overrightarrow{D}_{\mu} \varphi$ $O_{vq}^{(ij)}$ $(\phi^{\dagger} \overrightarrow{D}_{\mu} \varphi$ $O_{vu}^{(ij)}$ $(\phi^{\dagger} \overrightarrow{D}_{\mu} \varphi$ $O_{vu}^{(ij)}$ $(\phi^{\dagger} \overrightarrow{D}_{\mu} \varphi$ $O_{vu}^{(ij)}$ $(\phi^{\dagger} \overrightarrow{D}_{\mu} \varphi$ $(\phi^{\dagger} \overrightarrow{D}_{\mu} \varphi$ $(\phi^{\dagger} \overrightarrow{D}_{\mu} \varphi$ $(\phi^{\dagger} \overrightarrow{D}_{\mu} \varphi)$ <t< td=""><td>uark operators     \$</td><td><math display="block">O_{qqu}^{(ijkl)}</math> <math display="block">O_{qqq}^{(ijkl)}</math> <math display="block">O_{qqq}^{(ijkl)}</math> <math display="block">O_{qqq}^{(ijkl)}</math> <math display="block">O_{duu}^{(ijkl)}</math></td><td><math display="block">\begin{array}{c} \begin{array}{c} \text{Baryon- and lepton-number-violating} \\ \hline (q^{\bar{c}}_{\alpha c} eq_{\beta \beta}) (\overline{u^{\bar{c}}}_{b c} e_{l}) e^{\alpha \beta \gamma} \\ \hline (q^{\bar{c}}_{\alpha c} eq_{\beta \beta}) (\overline{q^{\bar{c}}}_{b \gamma} e \ell_{l}) e^{\alpha \beta \gamma} \\ \hline (q^{\bar{c}}_{\alpha \alpha} \tau^{I} eq_{\beta \beta}) (\overline{q^{\bar{c}}}_{b \gamma} \tau^{I} \varepsilon \ell_{l}) e^{\alpha \beta \gamma} \\ \hline (\overline{d^{\bar{c}}}_{i \alpha} u_{\beta \beta}) (\overline{u^{\bar{c}}}_{b \gamma} \epsilon \ell_{l}) e^{\alpha \beta \gamma} \end{array}</math></td><td></td><td>where we counted separately CP-conserving and CP-violating (CPV) parameters. They are collected in Table 61.1. Other less restricted scenarios, such as that obtained by imposing <math>U(2)_{p+i+d}</math> symmetry featuring additional 10 + 10 CPV degrees of freedom, or more restricted ones, such as <i>top-philic</i> scenario where it is assumed that new physics couples dominantly to the left-handed doublet and right-handed up-type quark singlet of the third generation as well as to bosons, featuring only 19+6 (CPV) degrees of freedom, are often considered. It is also customary to analyse top-quark flavor-changing neutral currents (FCNCs) separately as, at the tree level, they enter only quadratically. More details can be found in Ref. [12].</td></t<> | uark operators     \$   | $O_{qqu}^{(ijkl)}$ $O_{qqq}^{(ijkl)}$ $O_{qqq}^{(ijkl)}$ $O_{qqq}^{(ijkl)}$ $O_{duu}^{(ijkl)}$                | $\begin{array}{c} \begin{array}{c} \text{Baryon- and lepton-number-violating} \\ \hline (q^{\bar{c}}_{\alpha c} eq_{\beta \beta}) (\overline{u^{\bar{c}}}_{b c} e_{l}) e^{\alpha \beta \gamma} \\ \hline (q^{\bar{c}}_{\alpha c} eq_{\beta \beta}) (\overline{q^{\bar{c}}}_{b \gamma} e \ell_{l}) e^{\alpha \beta \gamma} \\ \hline (q^{\bar{c}}_{\alpha \alpha} \tau^{I} eq_{\beta \beta}) (\overline{q^{\bar{c}}}_{b \gamma} \tau^{I} \varepsilon \ell_{l}) e^{\alpha \beta \gamma} \\ \hline (\overline{d^{\bar{c}}}_{i \alpha} u_{\beta \beta}) (\overline{u^{\bar{c}}}_{b \gamma} \epsilon \ell_{l}) e^{\alpha \beta \gamma} \end{array}$ |                           | where we counted separately CP-conserving and CP-violating (CPV) parameters. They are collected in Table 61.1. Other less restricted scenarios, such as that obtained by imposing $U(2)_{p+i+d}$ symmetry featuring additional 10 + 10 CPV degrees of freedom, or more restricted ones, such as <i>top-philic</i> scenario where it is assumed that new physics couples dominantly to the left-handed doublet and right-handed up-type quark singlet of the third generation as well as to bosons, featuring only 19+6 (CPV) degrees of freedom, are often considered. It is also customary to analyse top-quark flavor-changing neutral currents (FCNCs) separately as, at the tree level, they enter only quadratically. More details can be found in Ref. [12].  |
|   | $\begin{array}{c} {}^{+}O_{\varphi ud}^{(J)} & (\bar{\varphi}^{\dagger}iD_{\mu}\varphi \\ {}^{+}O_{uW}^{(ij)} & (\bar{q}_{i}\sigma^{\mu\nu}T \\ {}^{+}O_{W}^{(ij)} & (\bar{q}_{i}\sigma^{\mu\nu}u_{j} \\ {}^{+}O_{W}^{(ij)} & (\bar{q}_{i}\sigma^{\mu\nu}u_{j} \\ {}^{+}O_{uW}^{(ij)} & ($  | $egin{array}{lll} arphi(ar{u}_i\gamma^\mu d_j) \ arphi^I u_j) \ arphi W^I_{\mu u} \ arphi^{I} d_j) \ arphi W^I_{\mu u} \ arphi^I d_j) \ arphi B_{\mu u} \ arphi^I d_j \ arph^I d_j \ arphi^I d_j \ arph^$ |   |  |                           | 61. Top Quark, page 4       (TEXT, chunk 14)       Score = 0.732         From section Couplings:       The currently adopted parametrization for SMEFT interpretations of top quark measurements relies on the Warsaw basis of gauge-invariant  |
| Table 6.1.1: List of SMEFT o<br>conventions, see reference        | ${}^{\dagger}O_{uG}^{(ij)}$ $(\bar{q}_i\sigma^{\mu\nu}T)$   | $\left[ {{{\cal F}}^{A}u_{j}}  ight) ar{arphi} G^{A}_{\mu u}$ on six, assuming $U$  | $U(2)_q 	imes U(q)_q$   | $(2)_u 	imes U(2)_d$ flavor symmetry. For more   | e details on notation and | dimension-six operators [11] and it is presented in Tab. 61.1 as detailed in Ref [12] (see [13, 14] for early discussions of top-quark related<br>operators). For convenience, often specific degrees of freedom are identified from combinations of Warsaw-basis operator coefficients<br>aligned with the directions of the EFT parameter space which appear in given processes, in interferences with SM amplitudes, and in top-<br>quark interactions with some of the gauge boson mass eigenstates. Model implementations are available for tree-level and even one-loop<br>Monte Carlo simulations.   |





- The new PDG API provides programmatic access to PDG data via three tools, aimed at different use cases
  - Data in JSON format from pdgLive (or via REST API)
  - Python API
  - SQLite database files
- Exploring recent AI (LLM) methods with the goal to provide enhanced searching of PDG data and reviews
  - Results from a first prototype are encouraging and are used to learn what matters and where improvement is needed
  - One of the hurdles is the 100% accurate conversion of PDG reviews into a suitable structured format such as Markdown





# **Extra Slides**



# **PDG Identifiers**



### How can one refer to desired particle physics quantities in a program?

- Easy for some things, e.g. for the charged pion  $\pi^+$ 
  - ASCII name: pi+
  - MC particle number: 211
- How about  $B^0 \to J/\Psi(1S)K^*(892)^0\pi^+\pi^-$  ?
- PDG defines digital object identifiers ("PDG Identifiers")
  - Case-insensitive, alphanumeric strings
    - First 4 alphanumeric characters typically denote particle, additional characters for properties
    - STRING.NUMBER for branching fractions
  - Examples
    - S008 for  $\pi^+$
    - S042.214 for the above decay
  - In most cases can e.g. iterate over quantities, but if
  - PDG Identifier is needed, can look it up e.g. in pdgLive





# Python API: Ambiguities and Pedantic Mode

t

- For properties such as mass, by default the Python API returns the
- "best" value
- Sometimes this is ambiguous
- In "pedantic mode", assumptions are avoided and one gets an exception in case of ambiguity

 $I(J^{P}) = 0(\frac{1}{2}^{+})$ 



Mass (direct measurements)  $m = 172.57 \pm 0.29 \text{ GeV} {[a,b]}$  (S = 1.5) Mass (from cross-section measurements)  $m = 162.5^{+2.1}_{-1.5} \text{ GeV} {[a]}$ Mass (Pole from cross-section measurements)  $m = 172.4 \pm 0.7 \text{ GeV}$ 

[1]: import pdg

```
[2]: api = pdg.connect()
top = api.get_particle_by_name('t')
[m.display_value_text for m in top.masses()]
[2]: ['172.57+-0.29', '162.5+2.1-1.5', '172.4+-0.7']
[3]: top.mass
[3]: 172.5746930968864
[4]: api = pdg.connect(pedantic=True)
top = api.get_particle_by_name('t')
top.mass
//
PdgAmbiguousValueError Traceback (most recent call last)
Cell In[4], line 3
1 api = pdg.connect(pedantic=True)
2 top = api.get_particle_by_name('t')
----> 3 top.mass
```



## **PDG Database Files**



## • PDG data in a single file in SQLite format

- Different versions can be downloaded from pdg.lbl.gov/api
- "pdgall" files contain historical summary data

| Database files                  |           |   |
|---------------------------------|-----------|---|
| The following database file are | currently | available (see documentation ):                     |
| Database file                   | Edition   | Description   |
| pdg-2024-v0.1.2.sqlite          | 2024      | Minimal data file as provided by Python package v0. |
| pdgall-2024-v0.1.2.sqlite       | 2024      | Ditto, but with historical Summary Table data       |

• Python API can use a downloaded file instead of the default data source, e.g.

api = pdg.connect("sqlite:///pdgall-2024-v0.1.2.sqlite")
len(api.editions), api.editions[:5]

(52, ['2024', '2023', '2022', '2021', '2020'])

