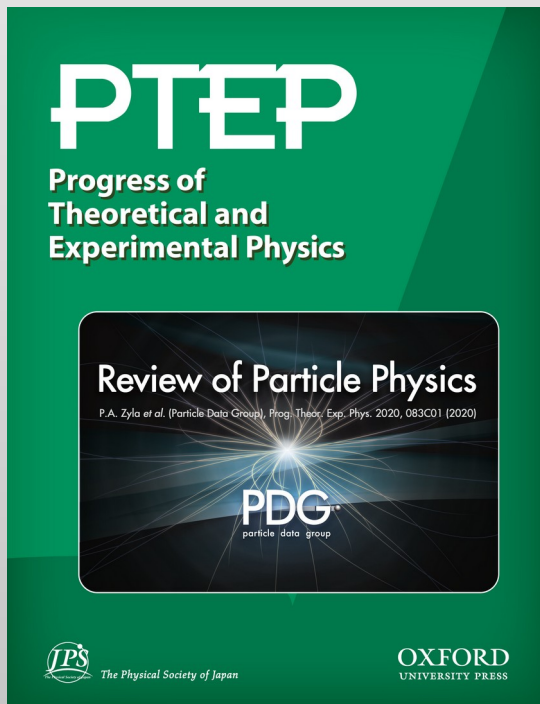


# PDG Collaboration News

**Juerg Beringer**

Physics Division

Lawrence Berkeley National Laboratory



## Outline

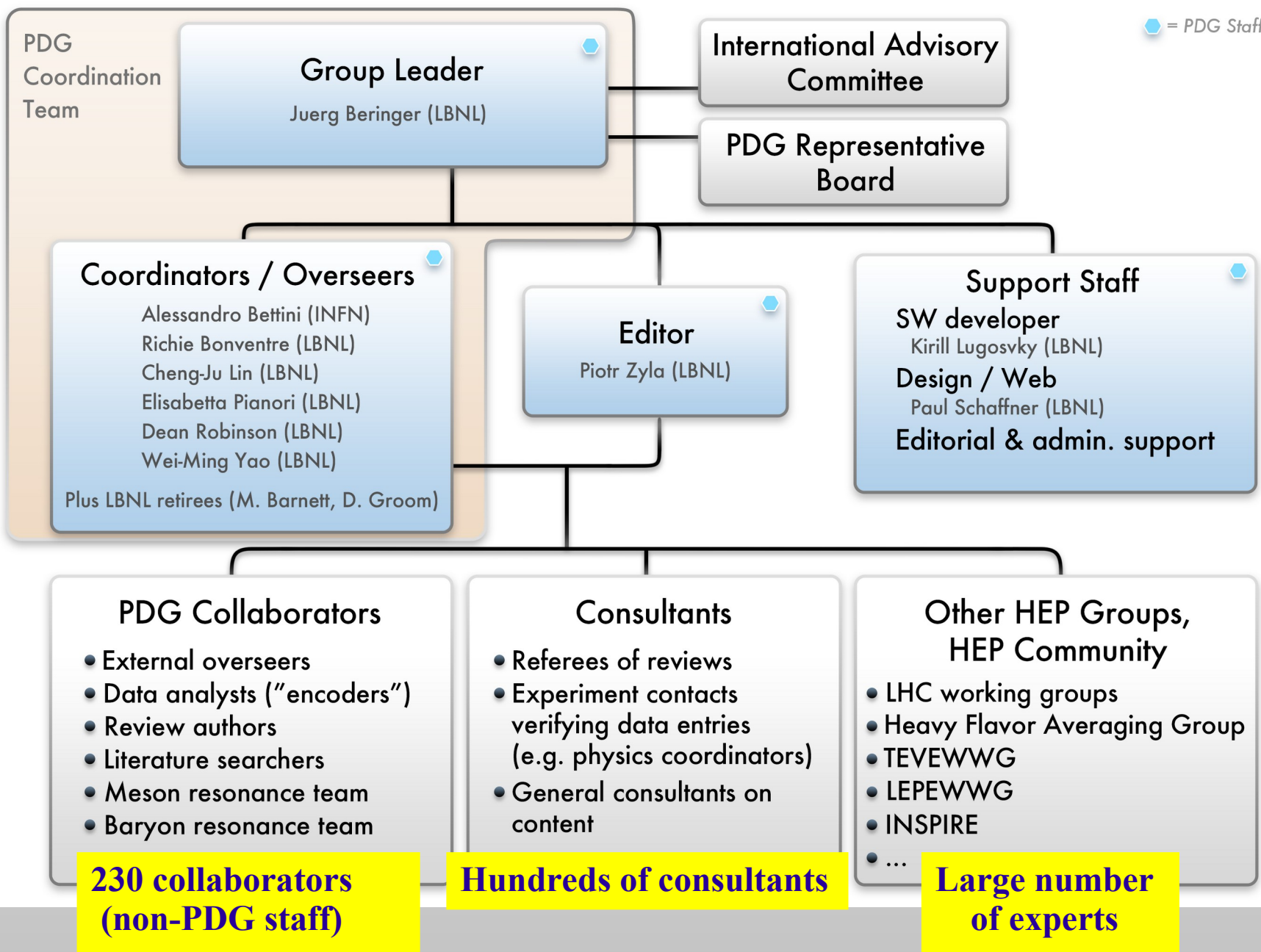
- Overview and some highlights
- Results from the PDG Booklet survey

- **First-ever virtual PDG (mini) Collaboration Meeting**
  - Thank you for attending – especially if it’s very early or late for you
    - **5am** on US West Coast ... **10pm** in Japan
- **Today’s meeting is a very scaled-down Collaboration Meeting with much fewer presentations/topics than usual**
  - Traditional in-person Collaboration/Advisory Committee Meetings will take place again when international travel is again feasible and safe
  - We plan additional online-only meetings every 3 to 6 months as needed for additional discussions
    - Will be at alternating times convenient for two of our three major time zones (Europe, US and Japan)
- **Logistics**
  - Cheng-Ju and Wei-Ming are available for **support** during the meeting
  - Richie Bonventre will moderate the discussion
    - **Please raise your “zoom hand” to speak** (speak directly if on phone)
    - **Will remind speakers with chime 5min before time is up**
  - After the presentations there will be **breakout rooms** to mingle

# Global PDG Collaboration



● = PDG Staff





# PDG Staff



Michael Barnett  
(retired July 2020)



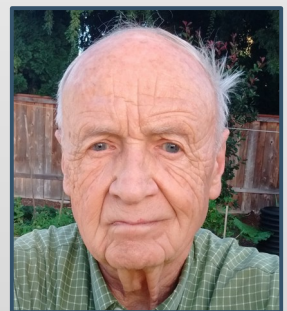
Juerg Beringer



Alessandro Bettini



Richie Bonventre  
(joined August 2020)



Don Groom



Cheng-Ju Lin



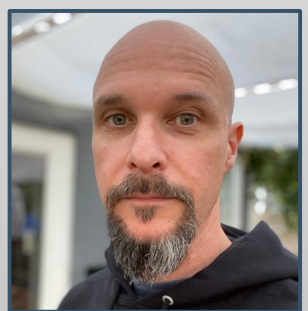
Kirill Lugovsky



Elisabetta Pianori



Dean Robinson  
(joined August 2019)



Paul Schaffner

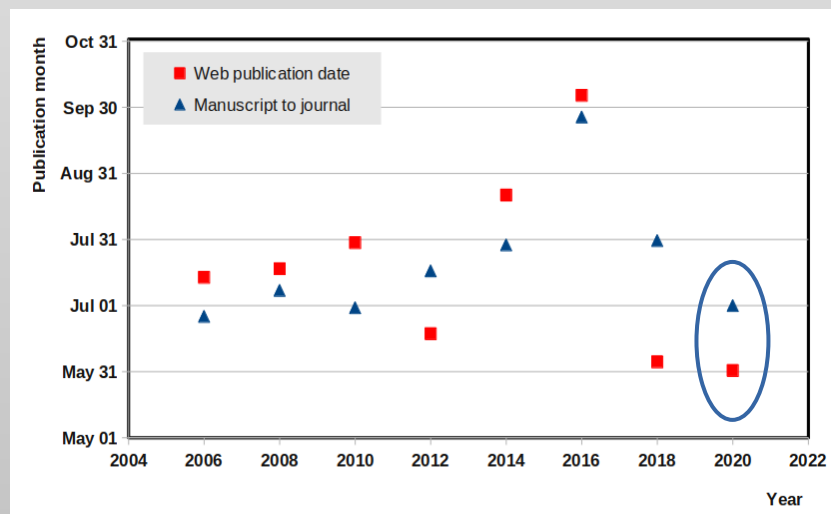


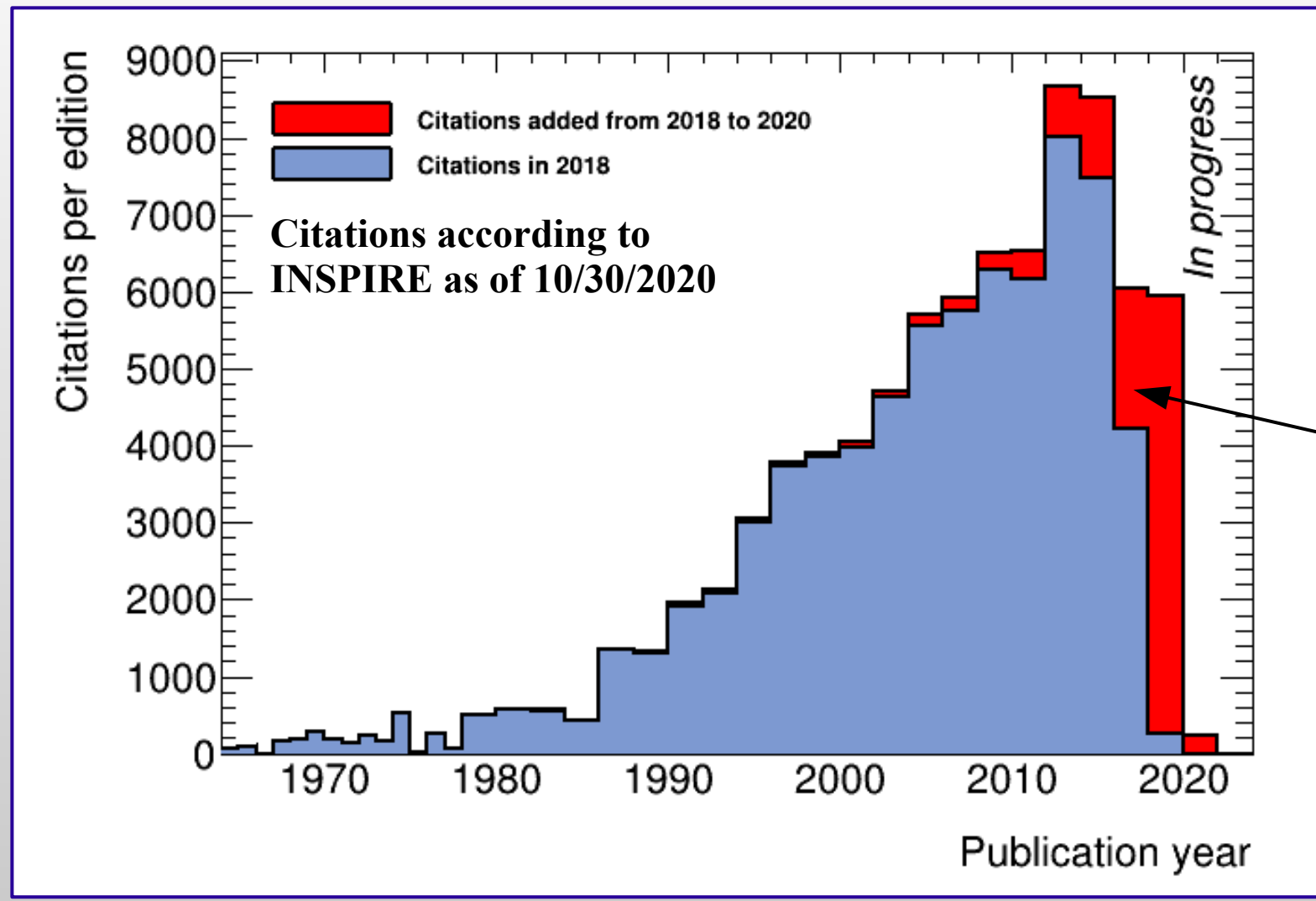
Wei-Ming Yao



Piotr Zyla

- **2020 Review of Particle Physics** published in **Prog. Theor. Exp. Phys. 2020, 083C01 (2020)**
  - Many thanks to the Physical Society of Japan (JPS)
  - Volume 1 (994p): **Summary Tables, review articles** → **PDG Book**
  - Volume 2 (1,098p): **Particle Listings**
- **3,324 new measurements from 878 papers added**
  - In addition to 41,371 meas. (11,322 papers) in previous editions
- **120 review articles, including 2 new ones**
  - *High Energy Soft QCD and Diffraction*
  - *Determination of CKM Angles from B Hadrons*
- **Consistently meeting deadlines allows again on-time publication**
  - In spite of COVID-19 and Bay Area power shutoffs due to fire danger





## More than 84,000 citations over all editions!



**NEW: PTEP publishes 2020 Review of Particle Physics**

**The Review of Particle Physics (2020)**  
P.A. Zyla et al. (Particle Data Group), Prog. Theor. Exp. Phys. 2020, 083C01 (2020).

pdgLive - Interactive Listings  
Summary Tables  
Reviews, Tables, Plots  
Particle Listings  
Search

**ORDER: Book & Booklet**

**Mobile Particle Physics Booklet 2018**

**DOWNLOAD: Book, Booklet, more**

Previous Editions (& Errata) 1957-2019	Physical Constants
Errata in current edition	Astrophysical Constants
Figures in reviews (2018)	Atomic & Nuclear Properties

**2020 Review of Particle Physics.**  
P.A. Zyla et al. (Particle Data Group), Prog. Theor. Exp. Phys. 2020, 083C01 (2020)

Gauge & Higgs Bosons	Leptons	Quarks
gluon graviton $W$ $Z$ $H$ Neutral Higgs Bosons, Searches for Charged Higgs Bosons ( $H^\pm, H^{\pm\pm}$ ) Heavy Bosons Axions	$\mu$ $\tau$ Heavy Charged Lepton Neutrino Properties Number of Neutrino Types Double $\beta$ Decay Neutrino Mixing Heavy Neutral Leptons	Light quarks ( $u, d, s$ ) $c$ $b$ $t$ $\nu$ Free quark

Mesons	Baryons	Other Searches
Light Unflavored Further States Strange Charmed Charmed, Strange Bottom Bottom, Strange Bottom, Charmed $c\bar{c}$ (including possibly non- $q\bar{q}$ states) $b\bar{b}$ (including possibly non- $q\bar{q}$ states) Non $q\bar{q}$ Candidates	$\Lambda$ Baryons $\Sigma$ Baryons $\Xi$ Baryons $\Omega$ Baryons Charmed Baryons Doubly-Charmed Bottom Baryons Exotic Baryons	Magnetic Monopole Supersymmetric Particles Technicolor Quark and Lepton Compositeness Extra Dimensions WIMPs Other Particle Searches

**Conservation Laws**

Discrete Space-Time Symm.  
Number Conservation Laws

Android and web app being tested, to be released soon

PDG  
particle data group

2020  
PARTICLE PHYSICS BOOKLET

Constants  
Summary tables  
Reviews  
About

PDG website (Listings, all review articles...)

Version 0.4.0, November 1, 2020

**OXFORD ACADEMIC** Progress of Theoretical and Experimental Physics

**PTEP** Progress of Theoretical and Experimental Physics

Review of Particle Physics  
Particle Data Group, P.A. Zyla, R.M. Barnett, J. Beringer, O. Dahi, D.A. Dwyer, D.E. Groom, C.-J. Lin, K.S. Lugovsky, E. Pianori ... Show more

Author Notes

Progress of Theoretical and Experimental Physics, Volume 2020, Issue 8, August 2020, 083C01, https://doi.org/10.1093/ptep/ptaa104  
Published: 14 August 2020

**Abstract**

The Review summarizes much of particle physics and cosmology. Using data from previous editions, plus 3,324 new measurements from 878 papers, we list, evaluate, and average measured properties of gauge bosons and the recently discovered Higgs boson, leptons, quarks, mesons, and baryons. We summarize searches for hypothetical particles such as supersymmetric particles, heavy bosons, axions, dark photons, etc. Particle properties and search limits are listed in Summary Tables. We give numerous tables, figures, formulae, and reviews of topics such as Higgs Boson Physics, Supersymmetry, Grand Unified Theories, Neutrino Mixing, Dark Energy, Dark Matter, Cosmology, Particle Detectors, Colliders, Probability and Statistics. Among the 120 reviews are many that are new or heavily revised, including a new review on High Energy Soft QCD and Diffraction and one on the Determination of CKM Angles from B Hadrons.

The Review is divided into two volumes. Volume 1 includes the Summary Tables and 98 review articles. Volume 2 consists of the Particle Listings and contains also 22 reviews that address specific aspects of the data presented in the Listings.

The complete Review (both volumes) is published online on the website of the Particle Data Group (pdg.lbl.gov) and in a journal. Volume 1 is available in print as the PDG Book, A Particle Physics Booklet with the Summary Tables and essential tables, figures, and equations from selected review articles is available in print and as a web version optimized for use on phones as well as an Android app.

**PTEP** Progress of Theoretical and Experimental Physics

**Review of Particle Physics**  
P.A. Zyla et al. (Particle Data Group), Prog. Theor. Exp. Phys. 2020, 083C01 (2020)

PDG  
particle data group

**OXFORD UNIVERSITY PRESS**

The Physical Society of Japan

Test sample

PDG  
particle data group

2020  
PARTICLE PHYSICS BOOKLET

Extracted from the Review of Particle Physics  
P.A. Zyla et al. (Particle Data Group), Prog. Theor. Exp. Phys. 2020, 083C01 (2020).  
See <http://pdg.lbl.gov/> for Particle Listings, complete reviews and pdgLive.  
Available from PDG at LBNL and CERN

Waiting for paper, printing should be completed ~Nov 25

Published in PTEP August 14, 2020

Being printed, should be ship from UK Nov 6



- **PDG web server moved to amazon cloud (AWS)**
  - Following last fall’s power shutoffs due to fire danger in the Bay Area
  - Production server remains at LBNL w/backup power after next week
- **LaTeX conversion ~completed successfully**
  - 92 reviews with 723 pages now in LaTeX
    - Conversion of 11 pages of tables/plots still in progress
  - 28 small “reviews” (mostly  $\ll 1$  page) in Listings must remain in TeX
  - Multiple improvements to PDG LaTeX environment available for next round of review updates (e.g. better support for wide tables, ...)

- **Many improvements in PdgWorkspace**
  - New Summary Tables tool
  - Support for cleanup tasks
  - ...

The screenshot shows the 'Summary Table Editor' interface. On the left, a table lists particle IDs and names: S043 W, S044 Z, S126  $H^0$ , S055 Neutral Higgs Bosons, Searches for, S064 Charged Higgs Bosons ( $H^\pm$  and  $H^{\pm\pm}$ ), S056 New Heavy Bosons, S029 Axions ( $A^0$ ) and Other, S003  $e$ , S004  $\mu$ , S035  $\tau$ , S025 Heavy Charged Lepton Searches, S800 Neutrinos, S066 Neutrino Properties, and --- Number of Neutrinos. The right pane shows the editor for S035  $\tau$ , displaying various physical properties and constraints such as mass, lifetime, and magnetic moment anomalies, with a 'CL = 95.0%' indicator.

- **Improved web portal with more features and better support for tablets and smartphones as well as a “full” PDG app**
  - New development project starting together with CERN
  - Scope and time scale still TBD
- **Making all PDG data available in machine readable format**
  - Python API
  - JSON (or XML) files via REST API
  - Downloadable database
- **Possible new review articles (still TBD)**
  - Heavy neutral leptons
  - Machine learning
  - Add new topics to Particle Detectors review (e.g. FPGA, light-weight support structures, ...)
- **Automating literature search using ML-based classification?**
  - Hoping for additional funding to investigate this



# Documentation for Collaborators



## Tools and Documentation for PDG Collaborators

Please note: this is a private area for PDG Collaborators only

### Schedule

- [Current schedule for 2021 updates \(revised 10/19/2020 with small shift of 1st encoding cycle deadlines\)](#)
- Previous schedules
  - [2020 edition](#)
  - [2019 web updates](#)
  - [2018 edition](#)
  - [2017 web updates](#)

### Responsibilities

- Your current responsibilities: see [PdgWorkspace](#) under *Settings > Responsibilities*.
- The *Responsibilities tool* in [PdgWorkspace](#) allows you to browse responsibilities by author or topic.
- To print a list of responsibilities, you can use the PDF files below. **However, they are updated only infrequently. For current responsibility assignments always check [PdgWorkspace](#).**
  - [Listing responsibilities as of 8/21/2020 \("chart of encoders and overseers"\)](#)
  - [Review responsibilities as of 8/21/2020](#)

### Meetings

- [2018 Collaboration and Advisory Committee meetings \(LBNL, Oct 25-27, 2018\)](#)
- Previous meetings: see [PDG meetings page](#)

### Online tools

- [PdgWorkspace](#) (PDG's web-based computing platform). This is the starting point for updating PDG Listings and reviews and is used by all PDG collaborators. This is where for instructions see links under Documentation below.
- [Particle Listings under revision \(except for unstable mesons - see below\)](#)
- [Meson Listings under revision](#)

### Documentation

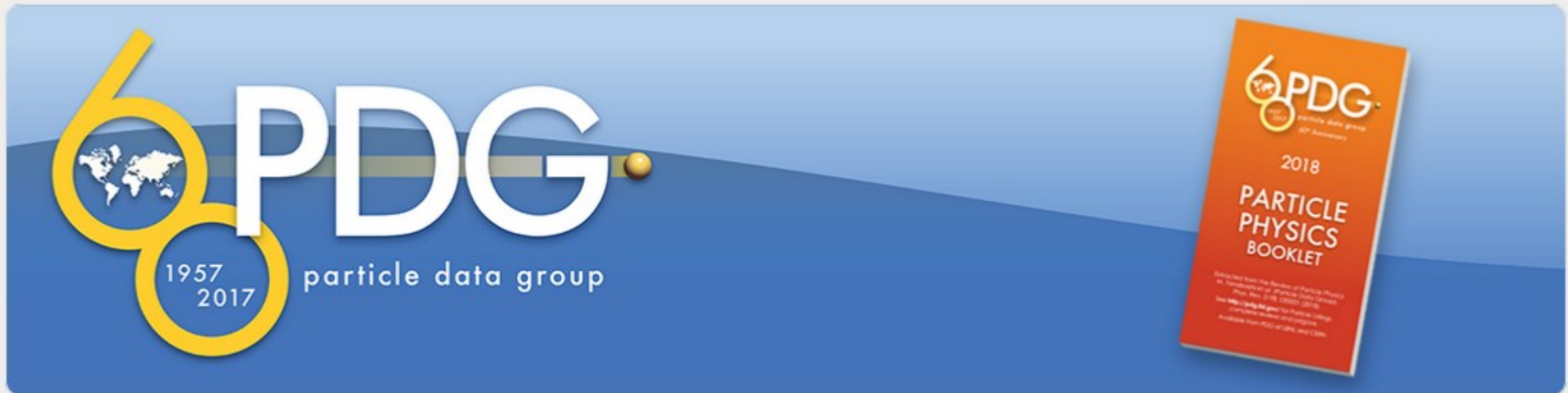
- [PDG Manual \(version 0.4\)](#)
- [Encoding documentation, including a video tutorial and many HowTo guides](#)
- [Review authoring documentation \(for reviews in LaTeX\), instructions and examples for writing reviews in LaTeX, and hints on installing and running LaTeX](#)
- Codes
  - [Institution codes](#)
  - [Journal codes](#)
  - [Technique codes and names](#)
  - [Particle codes in book order](#)
    - [without meson resonances \(pdf\)](#)
    - [for meson resonances \(sorted by particle node\)](#)
    - [except meson resonances](#)
- [PDG Technical Notes](#)
- [Computing documentation for developers \(protected\)](#)
- The [old encoding tools page](#) is still available, but is now obsolete and won't be updated anymore

### Contact information

- [support@pdg.lbl.gov](mailto:support@pdg.lbl.gov) - mailing list to request technical support (for technical issues, please use this list rather than contacting the editor directly)
- [editor@pdg.lbl.gov](mailto:editor@pdg.lbl.gov) or [pazyla@lbl.gov](mailto:pazyla@lbl.gov) to contact the editor (Piotr Zyla)
- [jberinger@lbl.gov](mailto:jberinger@lbl.gov) to contact the Head of PDG (Juerg Beringer)
- [Directions to Berkeley Lab](#)

On [pdg.lbl.gov](http://pdg.lbl.gov) see **PDG Authors > Encoder tools**, or directly at [pdgdoc.lbl.gov](http://pdgdoc.lbl.gov)

- PDG Schedule
- Responsibility lists
- PDG Manual
- Encoding tutorial video and HowTo guides
- ...



## PDG Booklet Survey

We need to decide whether PDG should continue to produce the Particle Physics Booklet (aka as "PDG Booklet"). Please complete this short (~1 minute) survey so we can judge the relevance of the Booklet to the community.

Please note that in addition to the printed Booklet there is now also a web version of the Booklet optimized for use on phones as well as an Android app (see <http://pdg.lbl.gov/booklet/>). Moreover, the full Review of Particle Physics continues to be available online, and the big PDG Book with Summary Tables and complete review articles will again be available in print in 2020.



- **Goals**

- Check if conclusions from discussions at 2018 PDG meetings as summarized in Advisory Committee report are still valid:

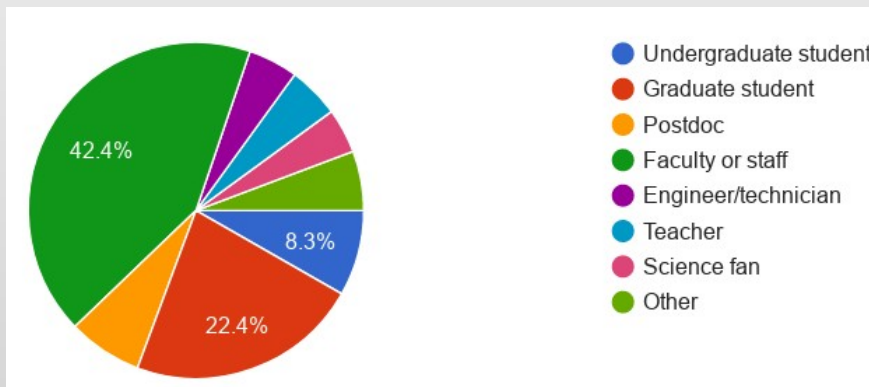
**Status of hard copies of PDG products**  
There is evidence that while the consumption of the hard copy of the RPP and the booklet might be decreasing, there exists a core section of the community, which finds the physical products extremely useful and appealing. We were also assured that the cost of printing and distributing are incremental to the total cost of PDG activities. The committee therefore concludes that there is no rational reason to discontinue the printed version as long as its cost is relatively minor compared to the overall PDG activities. We encourage PDG management to continue to monitor the shipping numbers and adjust the printing run sizes accordingly.

- Determine whether producing printed PDG Booklet is still useful in view of falling demand for printed products (about -12% / edition)

- **Survey timeline**

- 4/17/2020 Sent to PDG Collaboration, encouraging feedback
- 4/21/2020 Sent to everyone who ordered Book or Booklet since 2016 and agreed to receiving PDG e-mails
- **4/22/2020 3,900 responses within 24 hours**
- 5/6/2020 4,629 responses, closed survey

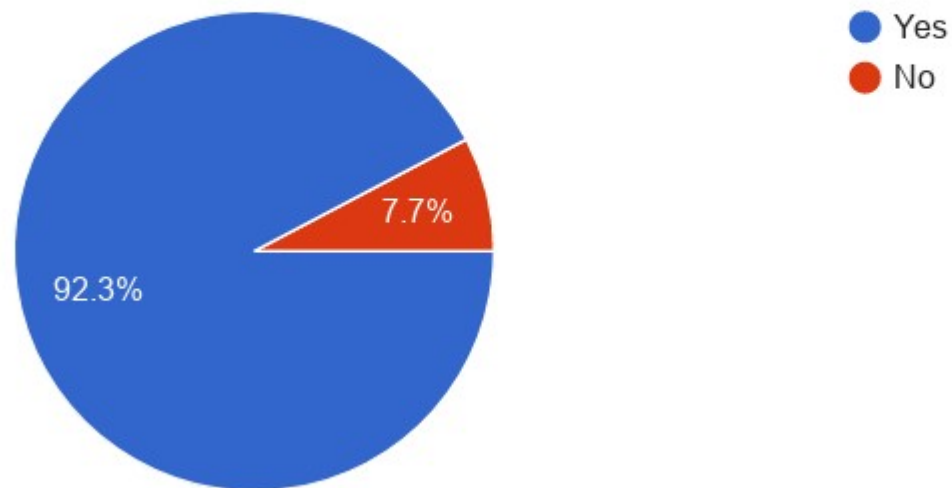
- **31% response rate (without sending any reminders!)**
  - **Very strong response – community clearly cares**
- **1,373 comments (87 pages in 11pt font)**
- **Responses come from all kinds of positions and all regions**



# Have a Booklet?

Do you currently have a copy of either the 2018 or the 2016 Booklet?

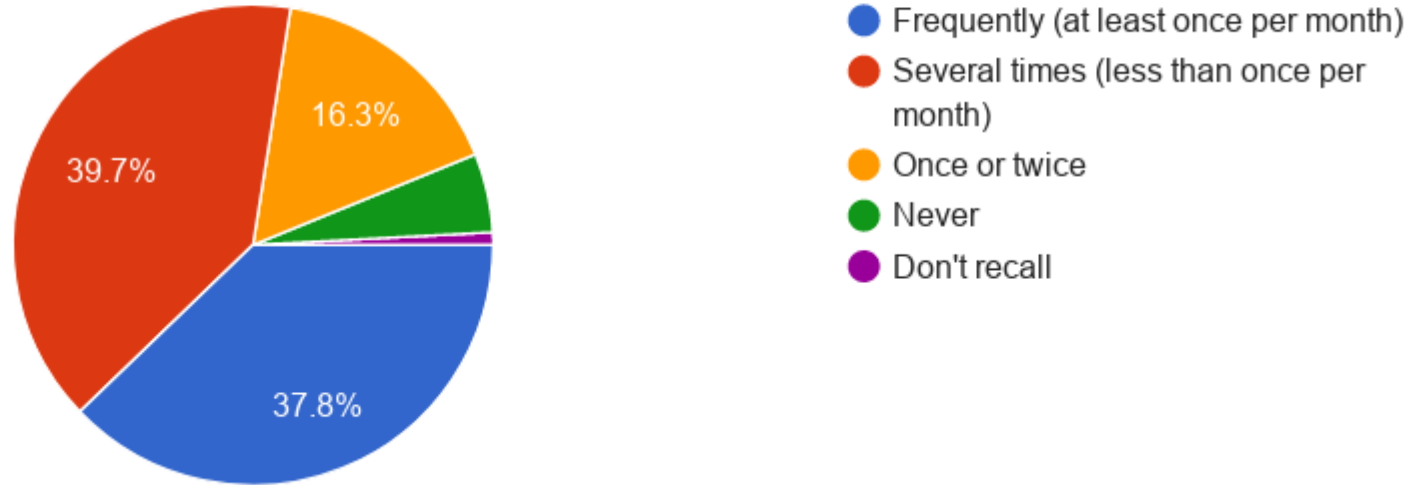
4,629 responses



- **96% of survey recipients ordered a Booklet in past 4 years**
- **Most seem to keep their Booklet for extended periods**

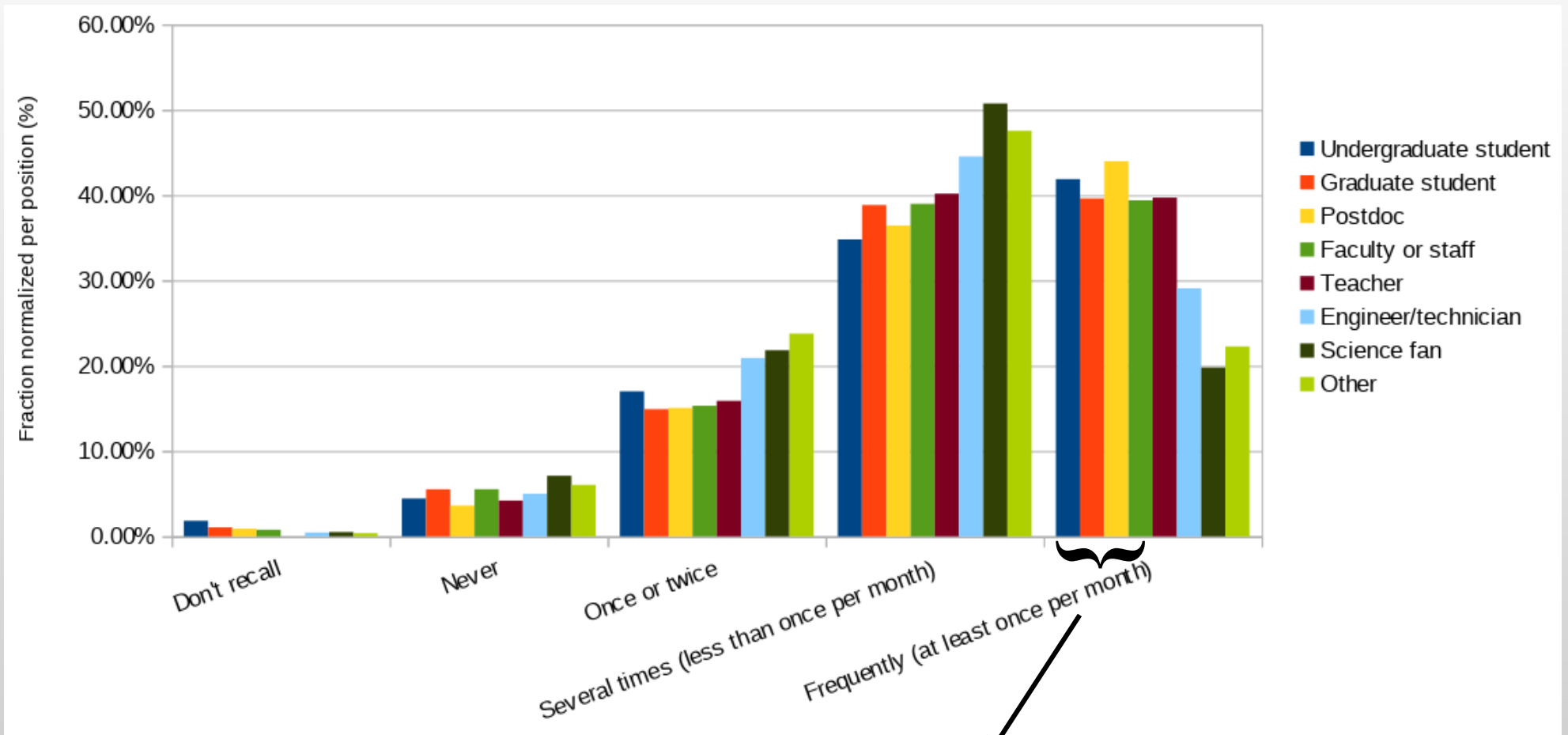
How often have you used a printed PDG Booklet - either your own or someone else's - in the past 12 months?

4,629 responses



- **Booklets are really used!**
  - 77% have used a Booklet multiple times in the past 12 months

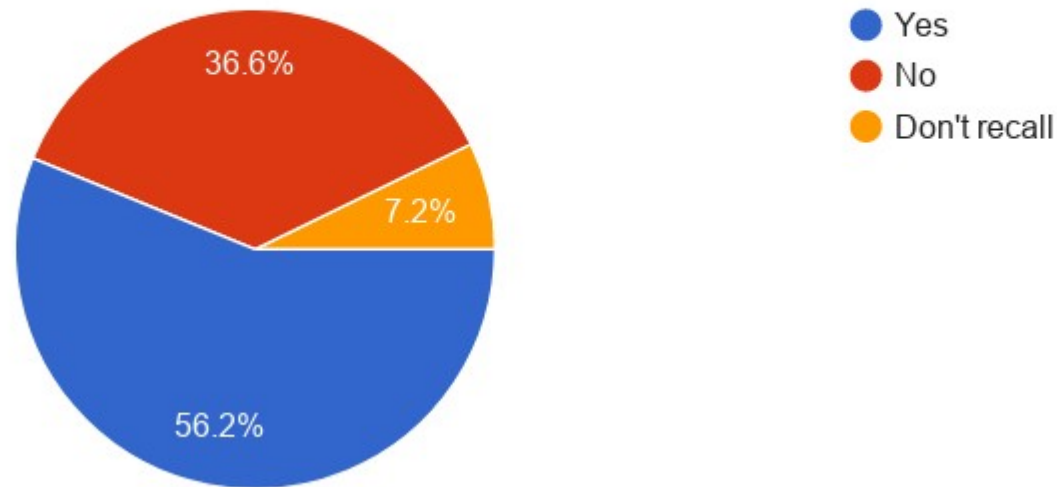




- **40% of responding students, Postdocs, faculty and staff use the Booklet frequently (at least once per month)**
  - No clear age dependency in this group

Have you ever used PDG Booklets in outreach or teaching activities?

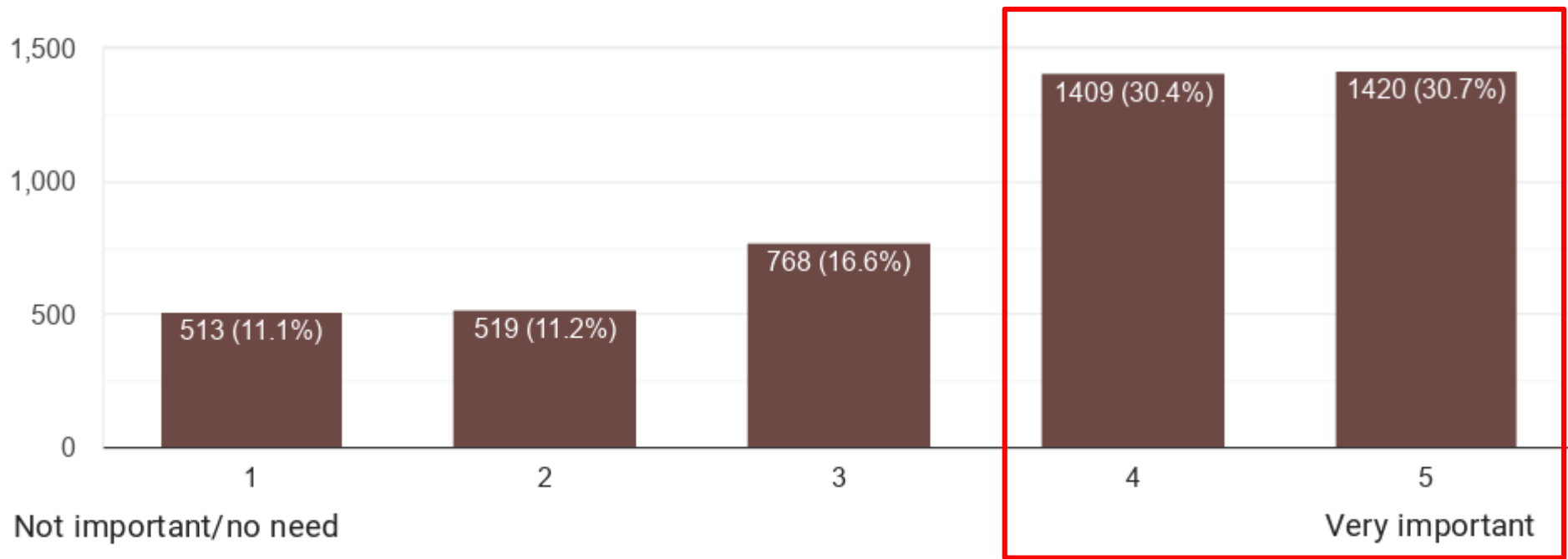
4,629 responses



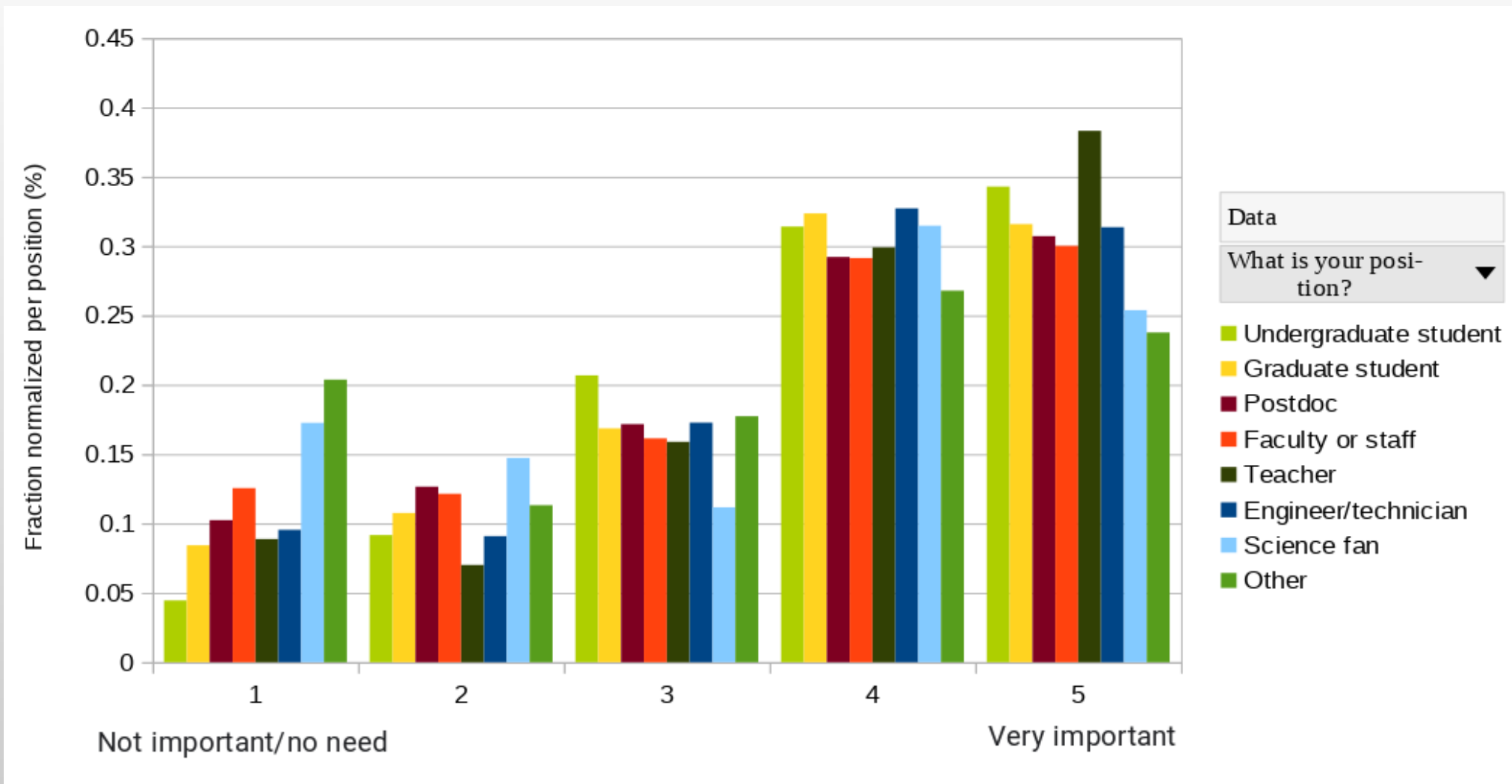
- **Booklets often used in outreach and teaching**
- **How much and in what way depends on position**
  - E.g. for undergraduates “teaching” means “being taught”

On a scale of 1 to 5, how important will the PRINTED version of the Booklet be for you in the future?

4,629 responses



- **61% view the printed Booklet as very important or important**

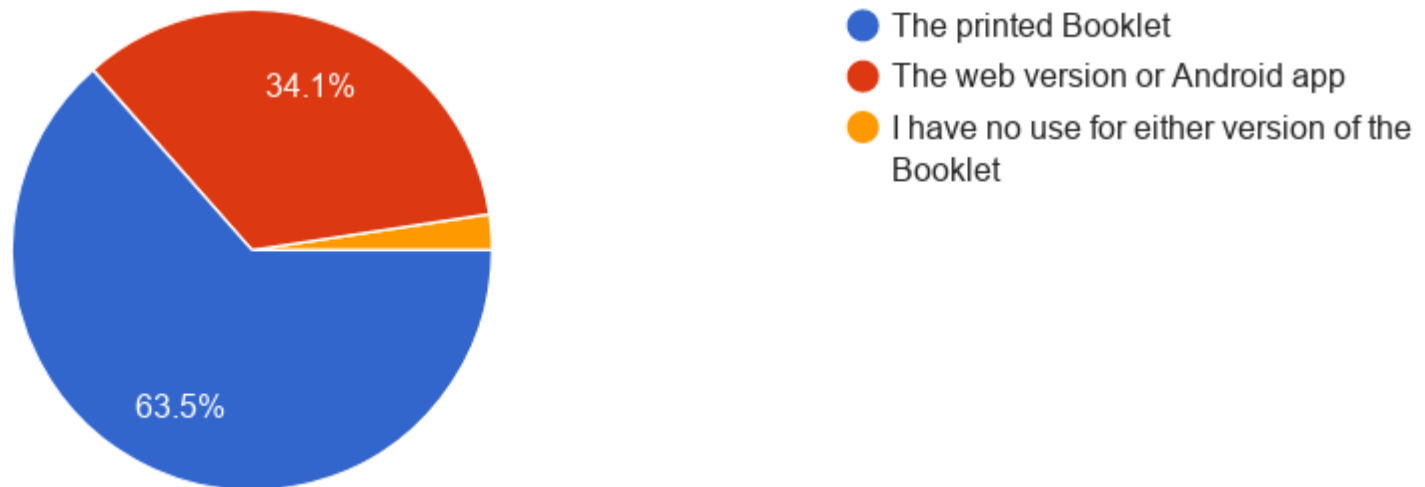


- **Undergrads and teachers want printed Booklet most**
  - It's not only old and nostalgic persons who want the Booklet



Given that there is now a web version of the PDG Booklet optimized for use on phones as well as an Android app (see <http://pdg.lbl.gov/booklet/>), which version of the Booklet do you prefer to use primarily in the future?

4,629 responses



- **65% of those who use the Booklet still prefer the printed one**
  - Note: no native iOS version, electronic versions became only available a few weeks before survey
- **Even barebones and very limited Booklet app very useful**

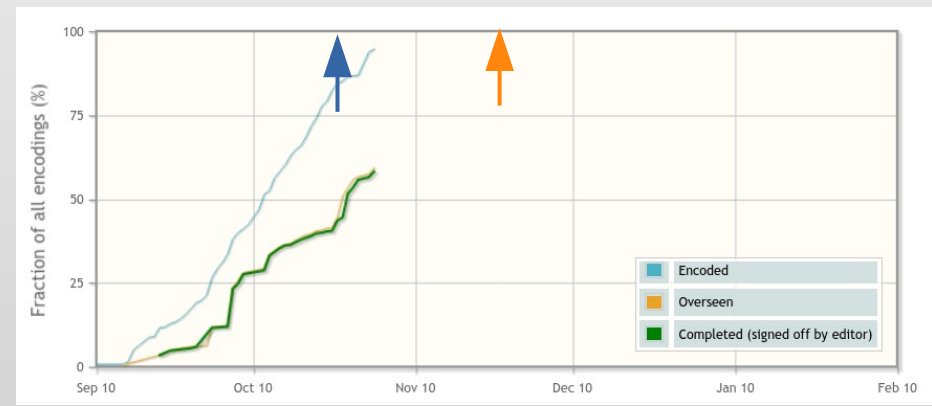
- **Some recurring themes in comments**
  - Wide range of opinions from no longer needing Booklets to absolutely wanting them (even suggesting DIY version if discontinued)
  - Many students want printed Booklet; used in exams (no phones)
  - Booklets are important tool for outreach and for motivating students
  - Not everyone always has good Internet access
  - Highlighting and sticky notes (print) vs searching (digital)
  - Flipping through pages, better for memorization
- **Key messages**
  - 61% of respondents say the **printed version of the Booklet will be very important (31%) or important (30%)** for them
  - Booklet is very important for **teaching and outreach**
  - 65% of those who use the Booklet prefer the printed version over the current Android app and web version
- **Based on this outcome and the strong response from the community, CERN agreed to continue the Booklet in 2020**

- **Publication schedule**

- Web update of Listings June 1, 2021
- Web update of review articles December 1, 2021
- Web publication of 2022 edition June 1, 2022

- **So far on track with current encoding cycle – thank you!**

- Encoder deadline: **Oct 25**
- Overseer deadline: **Nov 21**
- Timely completion essential to allow verification before holiday period



- **Crucial reminder for all review authors (for when the time comes to update your review)**

- **Always download latest version of source files from PdgWorkspace** before starting to update your review
- Please, never continue with files you have from a previous iteration

- **PDG continues to provide an essential service for the HEP community and beyond**
  - As evidenced by e.g. citations, use of online tools, downloads, demand for PDG products, and the outcome of the Booklet survey
  - Not only for research but equally for teaching and outreach
- **PDG is well**
  - Stable funding has allowed to maintain needed staffing level at LBNL
  - Your efforts to keep the various deadlines, combined with efficiency improvements in past years, are allowing
    - Timely publication of the Review of Particle Physics
    - Keeping production workload manageable

*Thank you  
for being part of PDG!*



# Backup Slides

- **Consists of representatives from the PDG Collaboration**
  - Main responsibility is to vet new PDG authors
- **Current members**
  - Michael Doser (CERN)
  - Simon Eidelman (Budker Inst., Novosibirsk State U.)
  - Ken-ichi Hikasa (Tohoku U.)
  - Cheng-Ju Lin (LBNL)
  - Keith Olive (U. Minnesota)
  - Ron Workman (George Washington U.)
  - Ex officio: Juerg Beringer (LBNL)

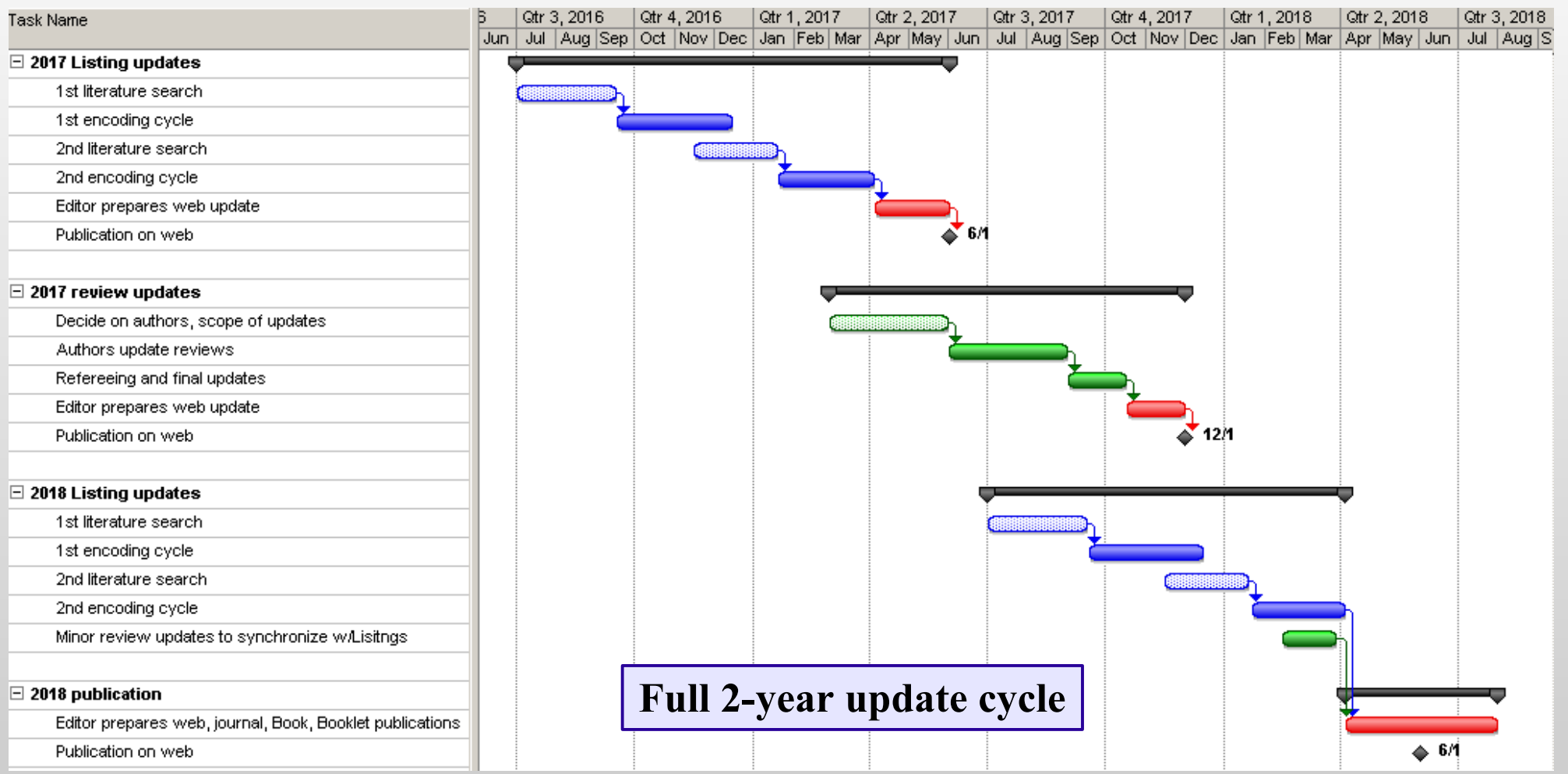
- **Current members**

- Sarah Demers (Yale)
- David d’Entierra (CERN)
- Josh Frieman (FNAL)
- Lawrence Hall (UC Berkeley, LBNL)
- Tatsuya Nakada (EPFL) - chair
- Masashi Yokoyama (Tokyo)
- Qiang Zhao (IHEP Beijing)

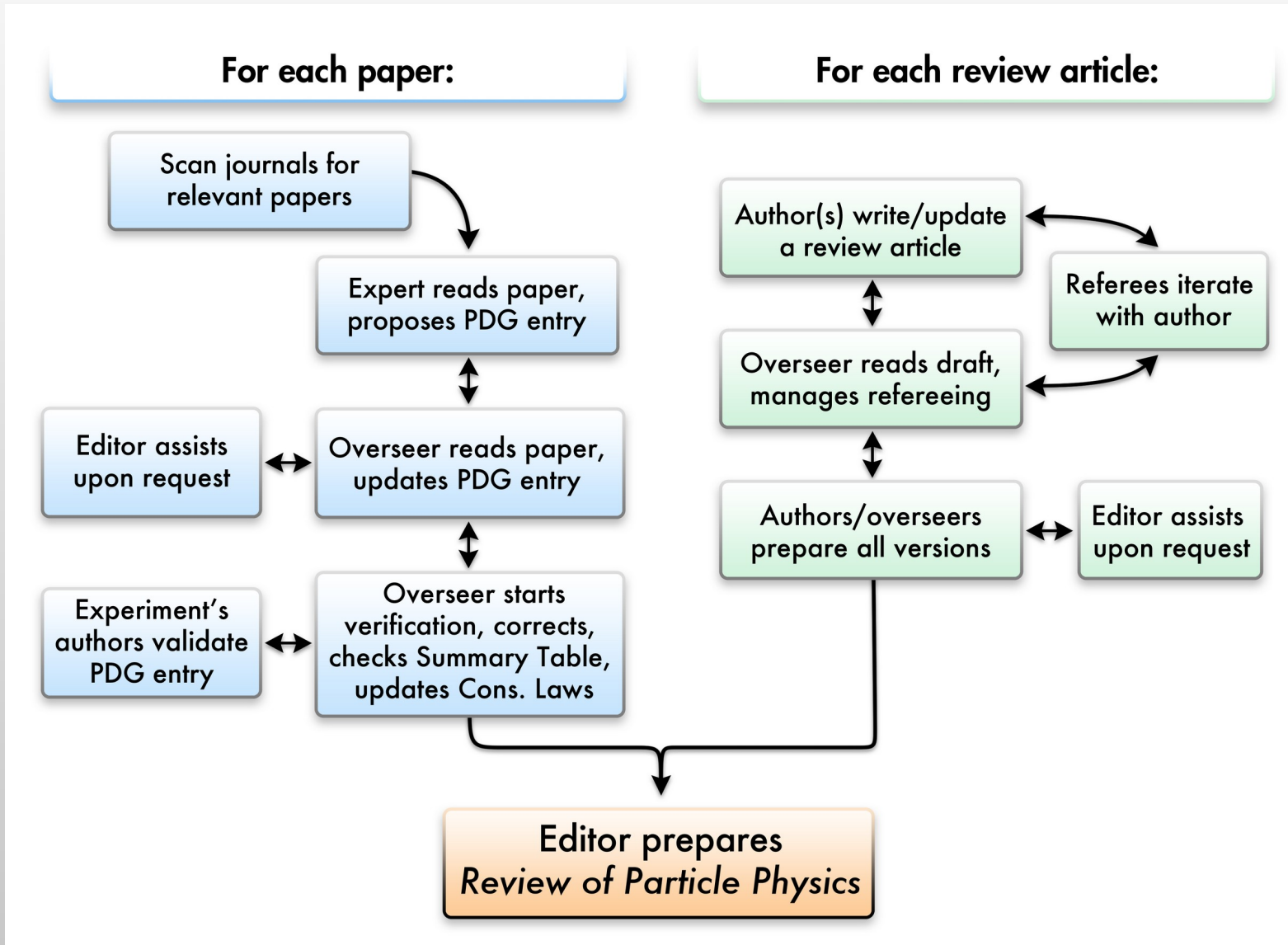
- **2018 committee members whose term ended**

- Abe Seiden (UCSC)
- Tancredi Carli (CERN)
- Anze Slosar (BNL)

# Schedule (Simplified)



Two encoding cycles





## Steps in authoring a PDG review

The normal progression of a PDG review through the authoring and



### 1 Introduction

#### 2 0.1 Overview

3 The *Review of Particle Physics* is a comprehensive review of the field of Particle Physics and of  
 4 related areas in Cosmology. It consists of "Summary Tables", "Reviews, Tables, and Plots", and  
 5 "Particle Listings". Starting with this edition, the *Review* is divided into two volumes. Volume 1  
 6 includes the Summary Tables and Reviews, Tables, and Plots with all review articles. Volume 2  
 7 consists of the Particle Listings. Review articles that were previously part of the Listings are now  
 8 included in Reviews, Tables and Plots in volume 1.  
 9 The contents of the *Review* are updated and made available on the PDG website (<http://pdg.lbl.gov>)  
 10 each year. In even-numbered years, the *Review* is published in a journal and made available in print  
 11 as the *PDG Book* together with an abridged *Particle Physics Booklet* containing Summary Tables  
 12 and essential tables, figures, and equations from selected review articles. This edition is an updating  
 13 through January 2018.  
 14 The Summary Tables give our best values and limits for particle properties such as masses,  
 15 widths or lifetimes, and branching fractions, as well as an extensive summary of searches for hypo-  
 16 theoretical particles and a summary of experimental tests of conservation laws.

**Draft version**

intro:sec:overview

### Introduction

#### 0.1 Overview

The *Review of Particle Physics* is a comprehensive review of the field of Particle Physics and of related areas in Cosmology. It consists of "Summary Tables", "Reviews, Tables, and Plots", and "Particle Listings". Starting with this edition, the *Review* is divided into two volumes. Volume 1 includes the Summary Tables and Reviews, Tables, and Plots with all review articles. Volume 2 consists of the Particle Listings. Review articles that were previously part of the Listings are now included in Reviews, Tables and Plots in volume 1.

The contents of the *Review* are updated and made available on the PDG website (<http://pdg.lbl.gov>) each year. In even-numbered years, the *Review* is published in

**Book version**

The last category only includes searches for particles that do not belong to the previous groups. For example, it includes searches for supersymmetric particles, compositeness and extra dimensions, while searches for heavy charged leptons and massive neutrinos are with the leptons.

In ?? of this Introduction, we list the main areas of responsibility of the authors of the Particle Listings. Our many consultants, without whom we would not have been able to produce this *Review*, are acknowledged in ??. In ??, we mention briefly the naming scheme for hadrons, which has been extended in this edition. In ??, we discuss our procedures for choosing among measurements of particle properties and for obtaining best values of the properties from the measurements.

**More details in tutorials and documentation**

- PDG provides an **authoritative, respected and comprehensive** summary of **particle physics and cosmology**
  - Draws broadly on the community for content
  - Small coordination team provides the scientific leadership, central coordination, and technical expertise
  - Headquartered at LBNL since inception
- **Main product: *Review of Particle Physics***
  - Provides summary and overview of the whole field **in a single place**
  - Yearly updates on the web
  - Journal publication every 2 years
  - Includes
    - **Summary Tables**
    - **Particle Listings**
    - **Reviews, Tables and Plots**
  - Available on the web, as journal publication, PDG Book, Booklet, ...

## PDG world averages for

- Particle masses
- Widths or lifetimes
- Branching fractions
- Magnetic moments
- Form factors
- Coupling constant ratios
- Limits
- ...

**$H^0$**

$J = 0$

Mass  $m = 125.18 \pm 0.16$  GeV

Full width  $\Gamma < 0.013$  GeV, CL = 95%

### $H^0$ Signal Strengths in Different Channels

See Listings for the latest unpublished results.

Combined Final States =  $1.10 \pm 0.11$

$W W^* = 1.08^{+0.18}_{-0.16}$

$Z Z^* = 1.14^{+0.15}_{-0.13}$

$\gamma\gamma = 1.16 \pm 0.18$

$b\bar{b} = 0.95 \pm 0.22$

$\mu^+\mu^- = 0.0 \pm 1.3$

$\tau^+\tau^- = 1.12 \pm 0.23$

$Z\gamma < 6.6$ , CL = 95%

$t\bar{t}H^0$  Production =  $2.3^{+0.7}_{-0.6}$

$H^0$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	Confidence level	$p$ (MeV/c)
$e^+e^-$	$< 1.9 \times 10^{-3}$	95%	62592
$J/\psi\gamma$	$< 1.5 \times 10^{-3}$	95%	62553
$\Upsilon(1S)\gamma$	$< 1.3 \times 10^{-3}$	95%	62234
$\Upsilon(2S)\gamma$	$< 1.9 \times 10^{-3}$	95%	62190
$\Upsilon(3S)\gamma$	$< 1.3 \times 10^{-3}$	95%	62163
$\phi(1020)\gamma$	$< 1.4 \times 10^{-3}$	95%	62587
$e\mu$	$< 3.5 \times 10^{-4}$	95%	62592
$e\tau$	$< 6.9 \times 10^{-3}$	95%	62579
$\mu\tau$	$< 1.43\%$	95%	62579
invisible	$< 24\%$	95%	—

## Detailed information on how PDG arrived at its averages

- Tables of published measurements with comments and footnotes
- Detailed fit information
- Information on consistency of measurements
- Associated review articles explaining aspects of data in Listings
- ...

$H^0$ MASS VALUE (GeV)	DOCUMENT ID	TECN	COMMENT
<b>125.18 ± 0.16 OUR AVERAGE</b>			
125.26 ± 0.20 ± 0.08	<sup>1</sup> SIRUNYAN	17AV CMS	$pp$ , 13 TeV, $ZZ^* \rightarrow 4\ell$
125.09 ± 0.21 ± 0.11	<sup>2,3</sup> AAD	15B LHC	$pp$ , 7, 8 TeV
• • • We do not use the following data for averages, fits, limits, etc. • • •			
125.07 ± 0.25 ± 0.14	<sup>3</sup> AAD	15B LHC	$pp$ , 7, 8 TeV, $\gamma\gamma$
125.15 ± 0.37 ± 0.15	<sup>3</sup> AAD	15B LHC	$pp$ , 7, 8 TeV, $ZZ^* \rightarrow 4\ell$
126.02 ± 0.43 ± 0.27	AAD	15B ATLS	$pp$ , 7, 8 TeV, $\gamma\gamma$
124.51 ± 0.52 ± 0.04	AAD	15B ATLS	$pp$ , 7, 8 TeV, $ZZ^* \rightarrow 4\ell$
125.59 ± 0.42 ± 0.17	AAD	15B CMS	$pp$ , 7, 8 TeV, $ZZ^* \rightarrow 4\ell$
125.02 <sup>+0.26 +0.14</sup> <sub>-0.27 -0.15</sub>	<sup>4</sup> KHACHATRY...15AM	CMS	$pp$ , 7, 8 TeV
125.36 ± 0.37 ± 0.18	<sup>2,5</sup> AAD	14W ATLS	$pp$ , 7, 8 TeV
125.98 ± 0.42 ± 0.28	<sup>5</sup> AAD	14W ATLS	$pp$ , 7, 8 TeV, $\gamma\gamma$
124.51 ± 0.52 ± 0.06	<sup>5</sup> AAD	14W ATLS	$pp$ , 7, 8 TeV, $ZZ^* \rightarrow 4\ell$
125.6 ± 0.4 ± 0.2	<sup>6</sup> CHATRCHYAN 14AA	CMS	$pp$ , 7, 8 TeV, $ZZ^* \rightarrow 4\ell$
122 ± 7	<sup>7</sup> CHATRCHYAN 14K	CMS	$pp$ , 7, 8 TeV, $\tau\tau$
124.70 ± 0.31 ± 0.15	<sup>8</sup> KHACHATRY...14P	CMS	$pp$ , 7, 8 TeV, $\gamma\gamma$
125.5 ± 0.2 <sup>+0.5</sup> <sub>-0.6</sub>	<sup>2,9</sup> AAD	13AK ATLS	$pp$ , 7, 8 TeV
126.8 ± 0.2 ± 0.7	<sup>9</sup> AAD	13AK ATLS	$pp$ , 7, 8 TeV, $\gamma\gamma$
124.3 <sup>+0.6 +0.5</sup> <sub>-0.5 -0.3</sub>	<sup>9</sup> AAD	13AK ATLS	$pp$ , 7, 8 TeV, $ZZ^* \rightarrow 4\ell$
125.8 ± 0.4 ± 0.4	<sup>2,10</sup> CHATRCHYAN 13J	CMS	$pp$ , 7, 8 TeV
126.2 ± 0.6 ± 0.2	<sup>10</sup> CHATRCHYAN 13J	CMS	$pp$ , 7, 8 TeV, $ZZ^* \rightarrow 4\ell$
126.0 ± 0.4 ± 0.4	<sup>2,11</sup> AAD	12AI ATLS	$pp$ , 7, 8 TeV
125.3 ± 0.4 ± 0.5	<sup>2,12</sup> CHATRCHYAN 12N	CMS	$pp$ , 7, 8 TeV

<sup>1</sup> SIRUNYAN 17AV use 35.9 fb<sup>-1</sup> of  $pp$  collisions at  $E_{cm} = 13$  TeV with  $pp \rightarrow ZZ^* \rightarrow 4\ell$  where  $\ell = e, \mu$ .

<sup>2</sup> Combined value from  $\gamma\gamma$  and  $ZZ^* \rightarrow 4\ell$  final states.

<sup>3</sup> ATLAS and CMS data are fitted simultaneously.

<sup>4</sup> KHACHATRYAN 15AM use up to 5.1 fb<sup>-1</sup> of  $pp$  collisions at  $E_{cm} = 7$  TeV and up to

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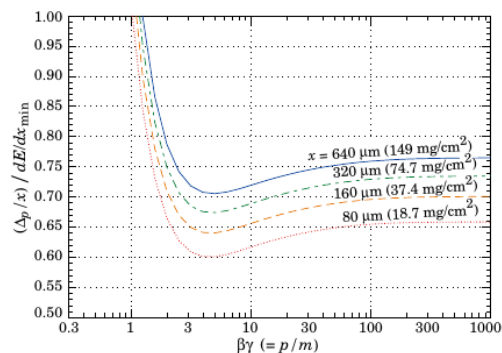
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## Review articles covering wide range of topics

- Constants, units, atomic & nuclear properties
- Standard Model
- Searches
- Astrophysics and cosmology
- Experimental methods, mathematical tools
- Colliders
- Reviews associated with Particle Listings
- ...

The most probable energy loss, scaled to the mean loss at minimum ionization, is shown in Fig. 33.9 for several silicon detector thicknesses.



**Figure 33.9:** Most probable energy loss in silicon, scaled to the mean loss of a minimum ionizing particle, 388 eV/μm (1.66 MeV g<sup>-1</sup>cm<sup>2</sup>).

If we define

$$\theta_0 = \theta_{\text{plane}}^{\text{rms}} = \frac{1}{\sqrt{2}} \theta_{\text{space}}^{\text{rms}}, \quad (33.14)$$

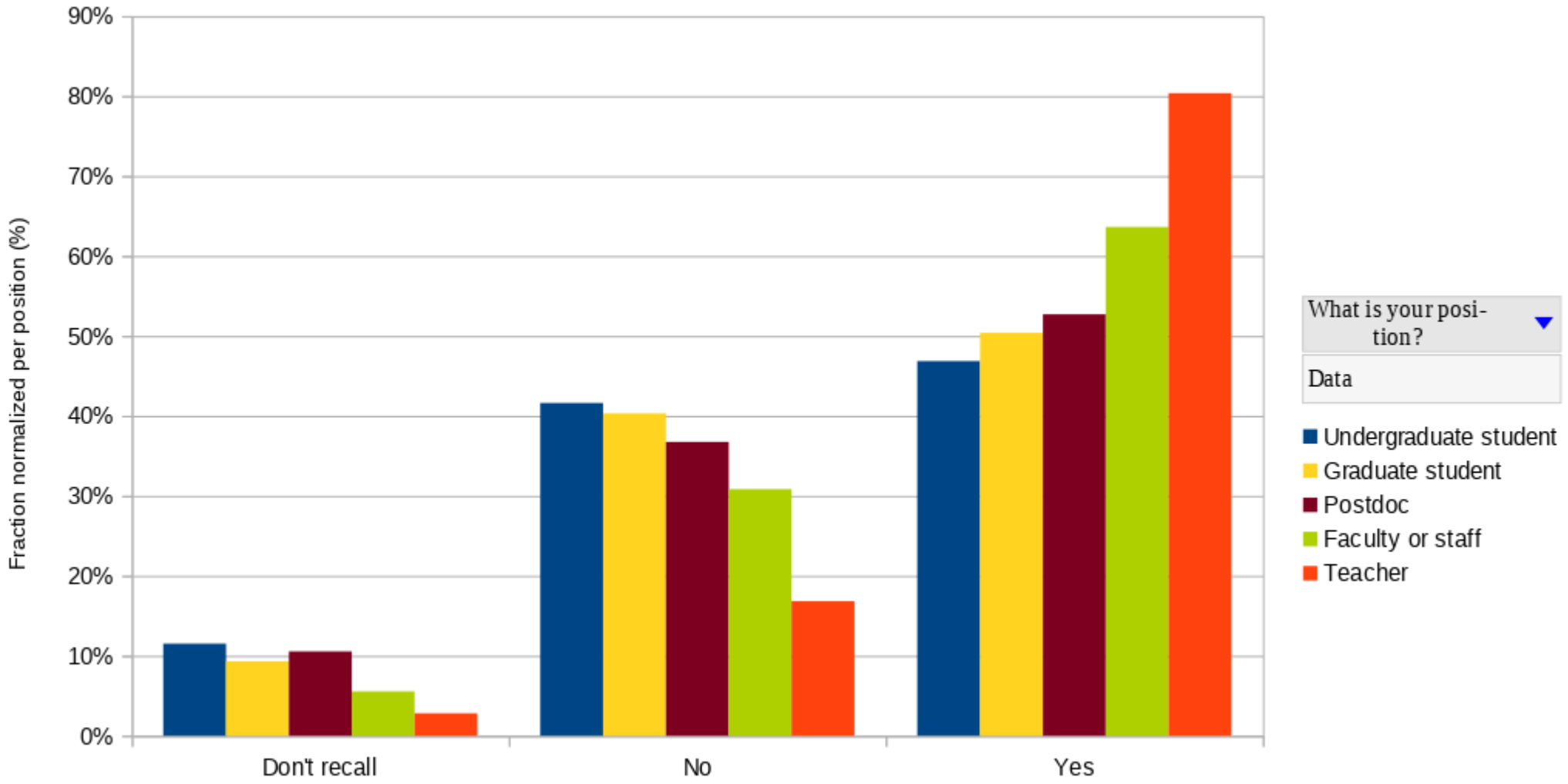
then it is sufficient for many applications to use a Gaussian approximation for the central 98% of the projected angular distribution, with an rms width given by Lynch & Dahl [39]:

$$\begin{aligned} \theta_0 &= \frac{13.6 \text{ MeV}}{\beta c p} z \sqrt{\frac{x}{X_0}} \left[ 1 + 0.088 \log_{10} \left( \frac{x z^2}{X_0 \beta^2} \right) \right] \\ &= \frac{13.6 \text{ MeV}}{\beta c p} z \sqrt{\frac{x}{X_0}} \left[ 1 + 0.038 \ln \left( \frac{x z^2}{X_0 \beta^2} \right) \right] \end{aligned} \quad (33.15)$$

Here  $p$ ,  $\beta c$ , and  $z$  are the momentum, velocity, and charge number of the incident particle, and  $x/X_0$  is the thickness of the scattering medium in radiation lengths (defined below). This takes into account the  $p$  and  $z$  dependence quite well at small  $Z$ , but for large  $Z$  and small  $x$  the  $\beta$ -dependence is not well represented. Further improvements are discussed in Ref. 39.

Eq. (33.15) describes scattering from a single material, while the usual problem involves the multiple scattering of a particle traversing many different layers and mixtures. Since it is from a fit to a Molière distribution, it is incorrect to add the individual  $\theta_0$  contributions in quadrature; the result is systematically too small. It is much more accurate to apply Eq. (33.15) once, after finding  $x$  and  $X_0$  for the

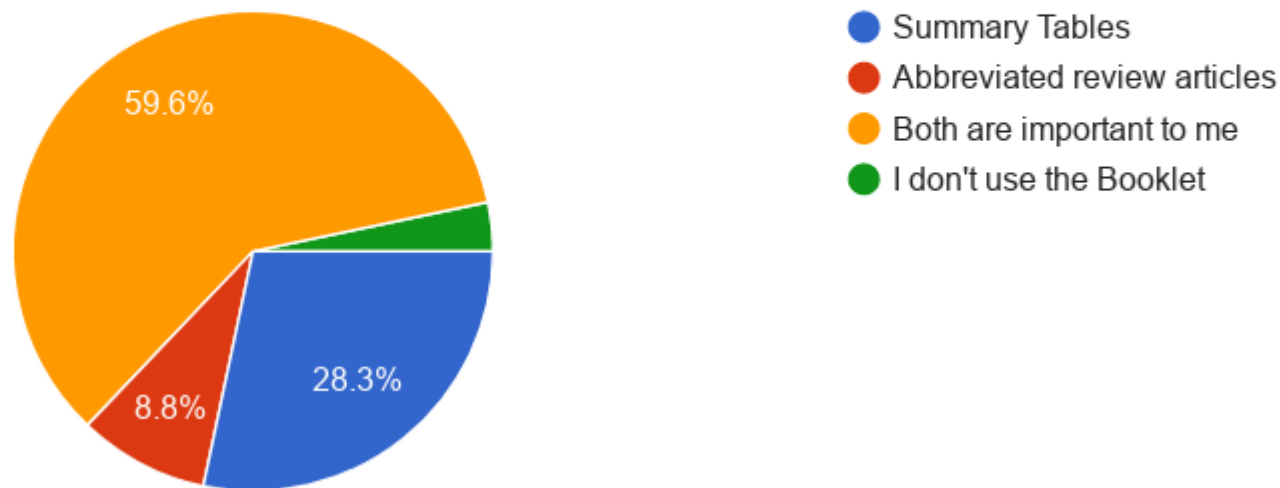




- **Some positions not relevant to teaching not shown in chart**
  - Not shown: Engineer/technician, Science fan, Other

The Booklet has two main sections: Summary Tables and selected abbreviated review articles with essential tables, figures and equations. What is most important for you?

4,629 responses



- **Summary Tables (88%) considered a bit more important than reviews (68%), but majority thinks both Summary Tables and reviews are important**