



## 56 Years of Review of Particle Physics

May 2013

Funded jointly by DOE, NSF and Japan/KEK

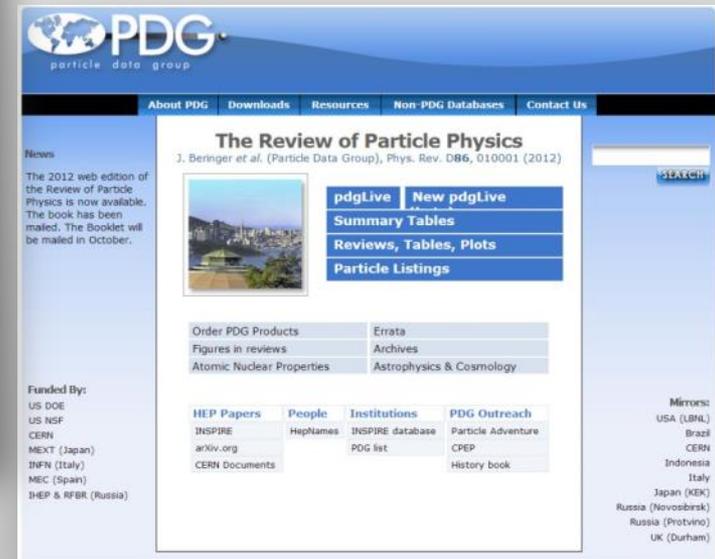
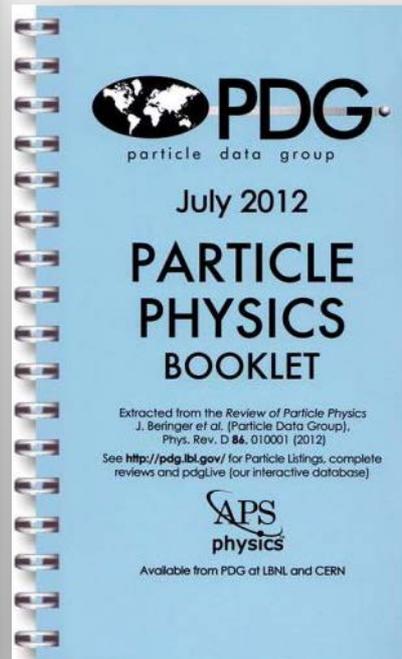
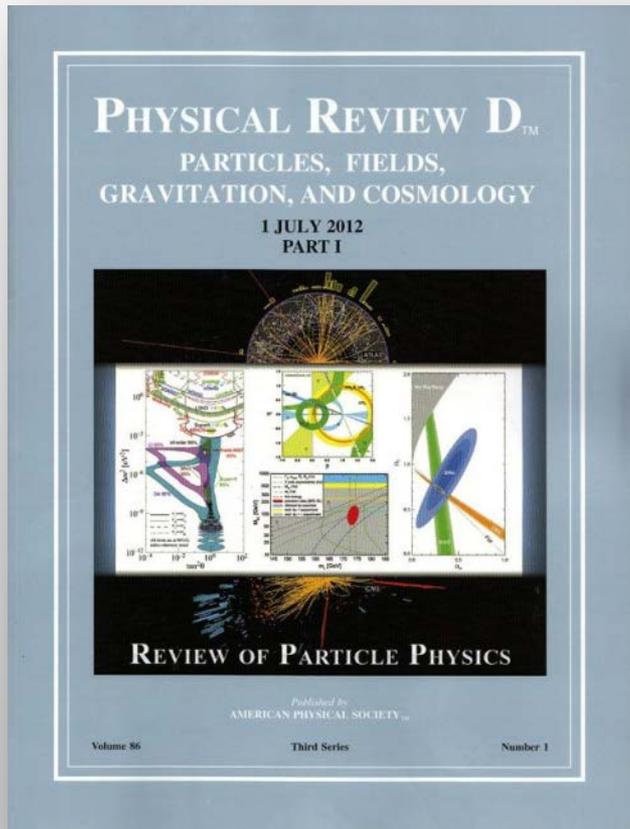
For the past 56 years, the data evaluations and review articles have been essential for progress in particle physics.

This summary of particle physics is vital to bring together the great discoveries, progress and understandings in the:

- energy frontier,
- intensity frontier,
- cosmic frontier.

The Review of Particle Physics is a dynamic product, ever-changing in response to the needs of researchers.

- 2012 Edition (book, booklet, web, pdgLive) **on schedule**
- 2013 Web Update to be completed **on schedule**





### ★ Berkeley Lab publishes 'Particle Physics Bible'

San Francisco Business Times by Steven E.F. Brown, Web Editor  
Date: Tuesday, June 19, 2012, 11:41am PDT - Last Modified: Tuesday, June 19, 2012, 3:05pm PDT

**Steven E.F. Brown**  
Web Editor - San Francisco Business Times  
Email

Have physicists found that elusive Higgs boson yet? Last I heard, they were confident of finding it around 125 gigaelectronvolts.

Well, if you haven't been keeping up on the latest work at the Large Hadron Collider, that 17 mile long particle accelerator buried under France and Switzerland, help is at hand in the form of the "Bible of particle physics," just published by [Lawrence Berkeley National Laboratory](#) .

The lab's Particle Data Group, made up of 200 scientists from 22 countries, has published the 1,422 page book known formally as the *Review of Particle Physics*. It



Enlarge Image

Ernest Orlando Lawrence (right) in 1934 with his cyclotron at Berkeley's Radiation Lab. He couldn't look up all those equations online, but thanks to his successors at the lab, you can!



### Latest edition of the 'Particle Physics Bible' now online

June 19, 2012

*The Review of Particle Physics*, a panorama of the world of high-energy and astroparticle physics, has been compiled and issued every two years since 1957 by the international Particle Data Group, now consisting of almost 200 scientists from 22 countries and based at the U.S. Department of Energy's Lawrence Berkeley National Laboratory (Berkeley Lab).



### New "particle physics Bible" released

June 19, 2012 | 10:10 am

Every two years, the international Particle Data Group, consisting of almost 200 scientists from 22 countries and based at Berkeley Lab, releases a new edition of *The Review of Particle Physics*. The 2012 edition, which runs over 1,400 pages long, was released online today.

Often referred to as "the Bible of particle physics," the publication compiles and summarizes published results related to particles and their interactions. It may sound a bit dry, but the book is incredibly useful—and ever-present in the lives of particle physicists and astrophysicists the world over.

This year's edition includes 2,658 new measurements from 644 papers, covering every subject of importance in both particle physics and cosmology—including the latest data on Higgs bosons, supersymmetry, *B* mesons, neutrinos, dark matter and more.

In total, the PDG's print editions have been cited in journals more than 41,000 times.

For more on *The Review of Particle Physics* and the Particle Data Group, see the [Berkeley Lab announcement](#).

- **193 authors** (leading experts) from 22 countries and 117 institutions
- Plus 700 consultants and experimentalists in the HEP community



**Research involvement has always been a keystone to the success (and quality) of PDG work.**

## **LBNL Physicists:**

Juerg Beringer	(ATLAS)
Cheng-Ju Lin	(Daya Bay)
Kathy Copic	(ATLAS)
Weiming Yao	(ATLAS)
Michael Barnett	(Theory, ATLAS)
Alex Cerri	(ATLAS)
Don Groom	(Ret., cosmology)
Orin Dahl	(Ret.)
Charles Wohl	(Ret.)
Piotr Zyla	(Editor)

## PDG leadership group at LBNL coordinates the entire effort

- Produces and publishes the Review,
- Handles all of the final checking, editing,
- Major contributor to the content,
- Chooses the authors and the content,
- Maintains the schedule
- Coordinates the input of 700 consultants from HEP community.

## Essential for

- High-quality
- Timely publication

Except for the PDG staff at LBNL, all work for PDG is carried out by volunteers who spend only a few percent of their time on PDG work

A crucial aspect of Particle Data Group is that we evaluate the data (accounting for correlations, etc.) and find best values.

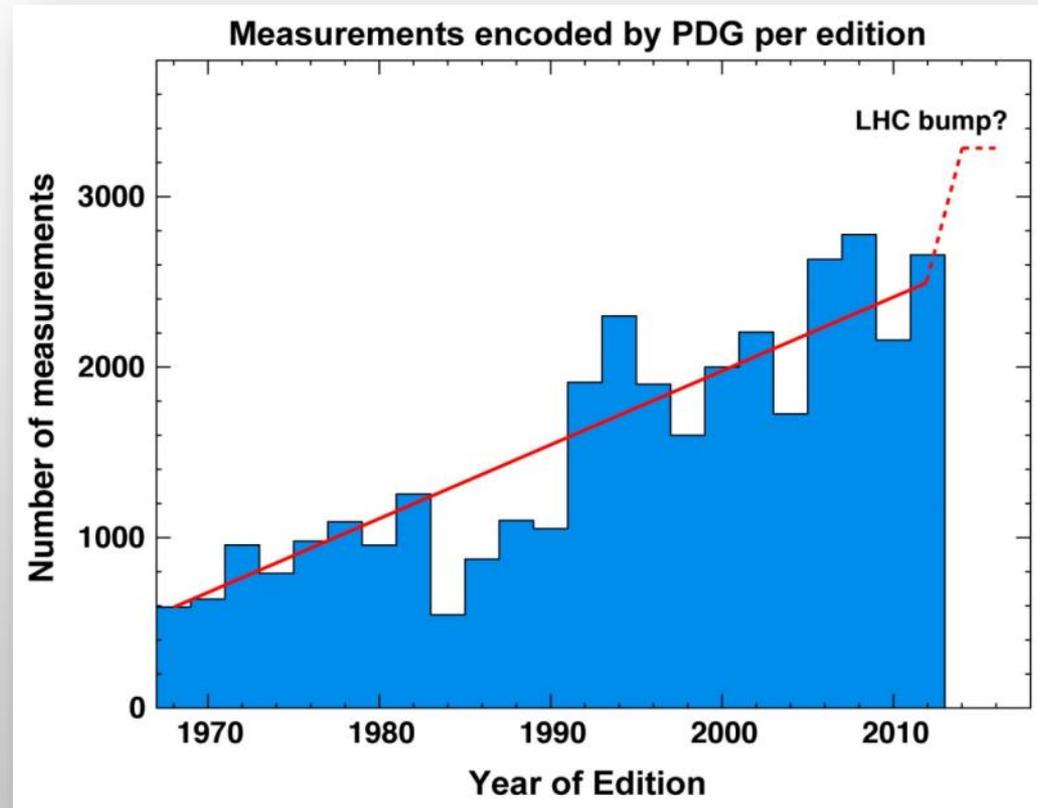
The PDG collaborates closely with specialized groups that are dedicated to providing averages and fits in specific areas:

- Newly formed LHC working groups:
  - Higgs
  - Top quark
  - etc.
- Tevatron Electroweak Working Group (TEVEWWG),
- Heavy Flavor Averaging Group (HFAG),
- LEP Electroweak Working Group (LEP EWWG).

PDG Workshop in June on searches in the post-Higgs era.

Follow PDG guidelines and practices for use in the Review.

Workload has increased dramatically. There is and will continue to be an explosion of papers from the LHC experiments, so we anticipate a “bump”.



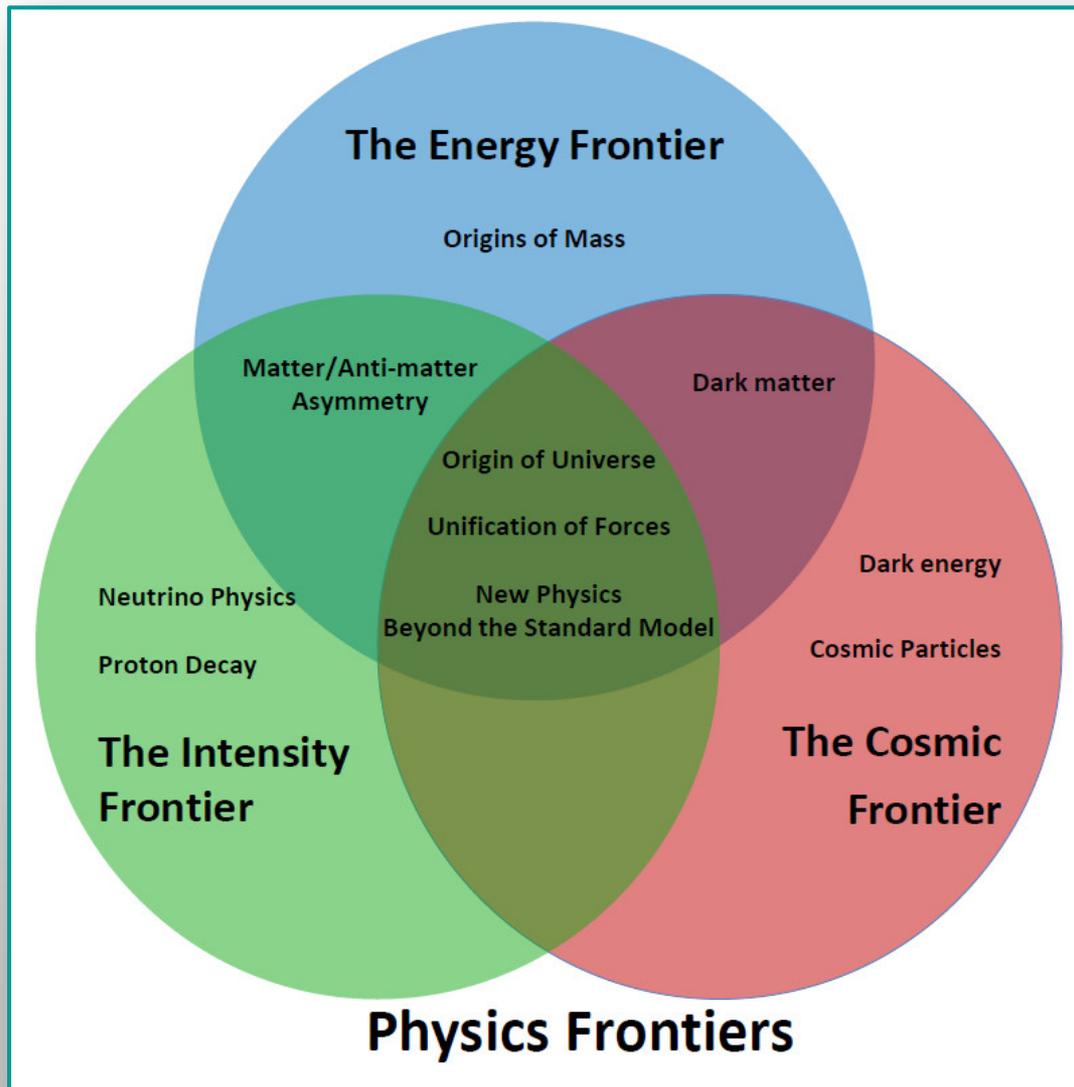
Each measurement needs to be fully understood in order to properly “encode” the data for the Review.

**Book editions in even years. Web update every year.**

- **2658** new measurements from **644** new papers  
(of total 32,100 measurements and 8900 papers).
- **112** reviews with many exciting and new features
- Important new data in areas such as  
Higgs, SUSY, neutrinos, top quark, B physics, etc.

★ **Color Figures everywhere**

# Broad Coverage



Total number of LHC papers: 41 ATLAS, 47 CMS and 18 LHCb papers.

LHC data exclude the Standard Model Higgs boson for substantial mass ranges (see later comments about last-minute addendum on Higgs discovery).

Major exclusions in SUSY results from the LHC.

Latest from B-meson physics: 120 papers with 555 measurements, including first LHCb results. Stringent limits on  $B_s \rightarrow \mu\mu$  from LHCb and CMS approaching the SM expectation.

Updated and new results in neutrino mixing, including observation of mixing angle  $\theta_{13}$  from reactor experiments.

63 new top quark results since 2010, many from LHC experiments.

New CDF/D0 value of W-mass with very small error, impact on prediction of Higgs mass.

New  $\eta_c(1S)$  branching ratio fit removing circular dependencies

First observations of  $h_b(1P)$ ,  $h_b(2P)$ , and the  $\chi_b(3P)$  triplet, as well as two exotic charged states with bottomonium content (unconfirmed)

## **New reviews on:**

- **Heavy-Quark and Soft-Collinear Effective Theory**
- **Neutrino Cross Section measurements**
- **Neutrino Beam Lines at High-Energy Proton Synchrotrons**
- **Monte Carlo Event Generators**
- **Lattice QCD**
- **Heavy quarkonium spectroscopy**

## Significant update/revision to reviews on:

- Astrophysical Constants (extended to include more cosmological parameters from the 7-year WMAP analysis)
- Dark Matter
- Top Quark with detailed coverage of LHC results
- $V_{cb}$ , and  $V_{ub}$  CKM elements
- Quantum Chromodynamics
- High-Energy Collider Parameters (includes CLIC and latest LHC parameters)
- Particle Detectors for Non-Accel. Physics (addition of Coherent Radio Cherenkov Detectors)

Astrophysics sections updated with the 7-year WMAP analysis.

Improved CPT invariance limit:  $m_K^0 - m_{\bar{K}^0} < 3 \times 10^{-19}$  GeV at 90% CL

Many review articles from the 2010 edition were downloaded more than 100,000 times each, including, for example:

- Higgs Boson,
- Passage of Particles through Matter,
- Particle Detectors for Accelerator-Based Physics,
- Statistics,
- Neutrino Mixing,
- Electroweak Model.

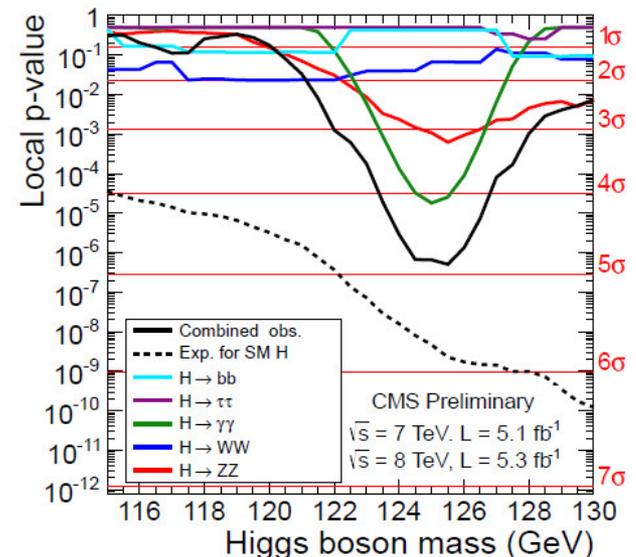
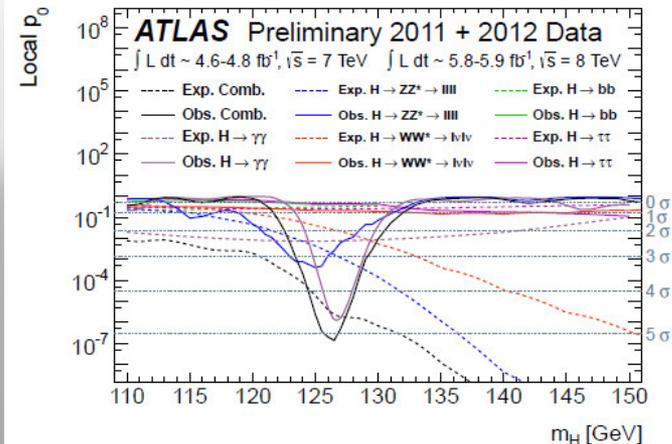
The cosmology reviews were downloaded more than **243,000 times** in total.

## Higgs Boson addendum

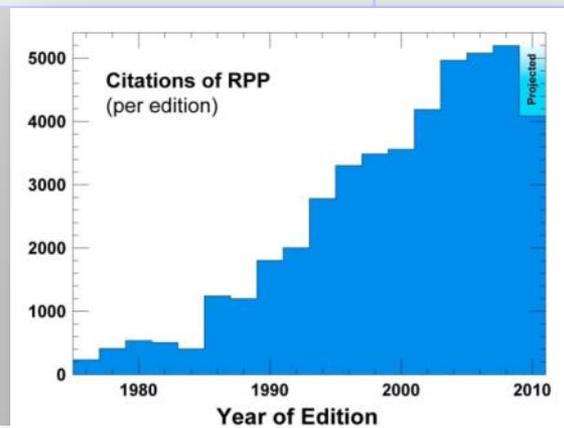
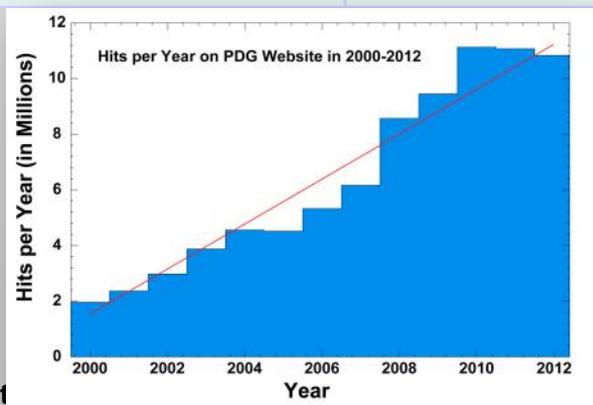
### VII. Addendum

Updated July 12, 2012.

On July 4, 2012, the ATLAS and CMS collaborations simultaneously announced observation of a new particle produced in  $pp$  collision data at high energies [363–366]. The data samples used correspond to between 4.6 and 5.1  $\text{fb}^{-1}$  of collision data collected at  $\sqrt{s} = 7$  TeV in 2011, and between 5.3 and 5.9  $\text{fb}^{-1}$  of collisions collected at  $\sqrt{s} = 8$  TeV in 2012. The observed decay modes indicate that the new particle is a boson. The evidence is strong that the new particle decays to  $\gamma\gamma$  and  $ZZ$  with rates consistent with those predicted for the Standard Model



	1984 Edition	2010 Edition
Citations	480	4092 → 5200 (asymp.)
Web Hits	Zero → 4 million in 2000 Ed.	22 million
Pages in Book	304	1525
Pages in Booklet	164	303 → 350 (size chg.)
Number distributed	4500 & 9000 (books & booklets)	15,000 & 31,000
Review articles	17	112
Measurements	547	2158 (2658 in 2012)
Authors	14 + 8 (meson)	180 + 13 (meson)



The Web allows us to see what most interest our readers.

The hits (page views) on

Data Listings = Reviews

almost exactly equal.

Clearly people care about both.

The HEP Community and many others depend on the PDG for accurate and objective information on the latest knowledge in particle physics.

In order to ensure the highest quality possible:

- All reviews in the Review of Particle Physics are refereed by 3-5 referees.
- Every item of data that is entered is checked by experiment(s) that produced the data (700 people help).
- The PDG Advisory Committee reviews all PDG operations. Last meeting at CERN, Fall 2012, chaired by Patrick Janot of CERN (CMS).

**The PDG Japan-US Collaboration has evolved into a very successful effort that produces materials used by physicists around the world.**

**The quality of the Review of Particle Physics is very much enhanced by the participation of Japanese physicists.**

**4460 products mailed to Japanese physicists (which they pay for).**

## Reviews and Data Sections

**Neutrinos**

**CKM Quark Mixing**

**Lattice QCD**

**Top quark & new quarks**

**Higgs bosons**

**Technicolor**

**Compositeness of quarks and leptons**

**Axions**

**Heavy bosons ( $W'$ ,  $Z'$ , leptoquarks,...)**

**WIMPS**

**Even more exotic particles.**

## Essential scientific contributions.

**Ten CERN members (as individuals):**

**Doser, Basaglia, Ceccucci, Giudice, Gurtu, Hoecker, Holtkamp, Roesler, Sauli, and Silari.**

**Support for the Meson Team (space, travel), which is mostly non-CERN people who meet at CERN.**

**Administration for CERN funding (Michael Doser).**

**CERN pays publisher directly for their copies.**

**Mirror website maintained.**

## Many years collaboration (> 20)

Coordination with SLAC Library group.  
SPIRES → Now INSPIRE (and CERN)

Yields our ability to link to the papers from which the measurements come.

Many discussions of improved coverage for the HEP community.



**PDG gets many comments and suggestions but by far the most common request is for a PDG app.**

**This would mean that every physicist could have the PDG tables and reviews in their pocket at all times.**

- **In the control room,**
- **On an airplane,**
- **In their office.**



To be accomplished in steps.

Zeroth version: Prototype by summer high school student.

First version: Smartphone-readable Summary Tables and some Reviews.

Second version: Data Listings (PDF).

Most desirable and most difficult would be a version of pdgLive for smartphones and tablets.

## SUMMARY TABLES OF PARTICLE PROPERTIES

Extracted from the Particle Listings of the  
*Review of Particle Physics*  
 J. Beringer *et al.* (PDG), PR D86, 010001 (2012)  
 Available at <http://pdg.lbl.gov>  
 ©2012 Regents of the University of California  
 (Approximate closing date for data: January 15, 2012)

### GAUGE AND HIGGS BOSONS

**$\gamma$**

$$I(J^{PC}) = 0,1(1^{--})$$

Mass  $m < 1 \times 10^{-18}$  eV  
 Charge  $q < 1 \times 10^{-35}$  e  
 Mean life  $\tau = \text{Stable}$

**$g$   
or gluon**

$$I(J^P) = 0(1^-)$$

Mass  $m = 0$  [a]  
 SU(3) color octet

**graviton**

$$J = 2$$

Mass  $m < 7 \times 10^{-32}$  eV

**$W$**

$$J = 1$$

Charge =  $\pm 1$  e  
 Mass  $m = 80.385 \pm 0.015$  GeV  
 $m_Z - m_W = 10.4 \pm 1.6$  GeV  
 $m_{W^+} - m_{W^-} = -0.2 \pm 0.6$  GeV  
 Full width  $\Gamma = 2.085 \pm 0.042$  GeV  
 $\langle N_{\pi^\pm} \rangle = 15.70 \pm 0.35$   
 $\langle N_{K^\pm} \rangle = 2.20 \pm 0.19$   
 $\langle N_p \rangle = 0.92 \pm 0.14$   
 $\langle N_{\text{charged}} \rangle = 19.39 \pm 0.08$

$W^-$  modes are charge conjugates of the modes below.

$W^+$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	Confidence level	$p$ (MeV/c)
$\ell^+ \nu$	[b] (10.80 $\pm$ 0.09) %		–
$e^+ \nu$	(10.75 $\pm$ 0.13) %		40192
$\mu^+ \nu$	(10.57 $\pm$ 0.15) %		40192
$\tau^+ \nu$	(11.25 $\pm$ 0.20) %		40173
hadrons	(67.60 $\pm$ 0.27) %		–

## Now:

Astrophysical Constants

Big Bang Cosmology

Cosmological Parameters:

$H_0$ ,  $\Lambda$ ,  $\Omega$ , etc.

Experimental Tests of

Gravitational Theory

Dark Matter

Cosmic Background Radiation

Cosmic Rays

➡ **Coming soon: Dark Energy**

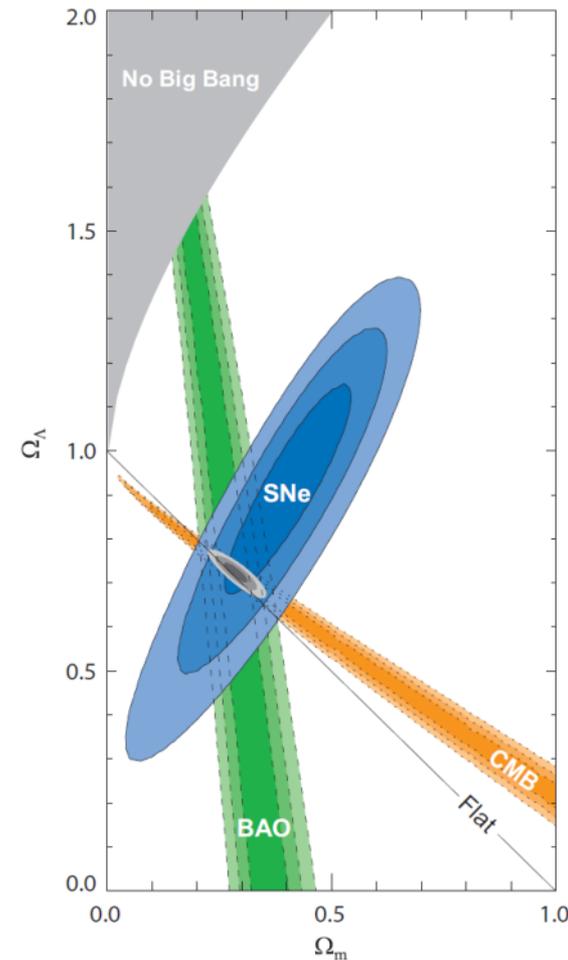


Figure 21.1: Confidence level contours of 68.3%, 95.4% and 99.7% in the  $\Omega_\Lambda$ - $\Omega_m$  plane from the CMB, BAOs and the Union SNe Ia set, as well as their combination (assuming  $w = -1$ ). [Courtesy of Kowalski *et al.* [25]]

- A table (or matrix of tables) of cosmological parameters similar to those at <http://lambda.gsfc.nasa.gov/product/map/current/parameters.cfm> perhaps with more entries such as sum of neutrino masses. One could also have a triangle of plots of the 2D confidence contours for each pair of major parameters.
- Review article on cosmological constraints on sum of neutrino masses, discussing the various probes, and limits under which assumption.
- Review article on cosmological distance measurements, or table of distance measurements to various redshifts.
- Review article on cosmological growth measurements, or table of growth measurements to various redshifts.
- Expanded coverage of testing non-Gaussianity, inflation models.

With thanks to Eric Linder

**PDG has long history of contributions to education and outreach:**

- **Particle Physics Booklet**
- **Particle Adventure**
- **Fundamental Particles and Interactions chart**
- **ATLAS outreach**
- **...and much more**

**And now...**



From Big Bang to galaxies to underground searches to the LHC.  
Fundraising completed and project is underway (9-12 months)

☀ 110 million people a year watch planetarium shows. ☀



## Team includes

- Academy Award-winning actress as narrator
- Award-winning scriptwriter & producer
- Famous band member as composer
- Nobel Prize-winning cosmologist
- Experts from seven planetariums

- ★ Play a leading role in understanding and summarizing new physics results from LHC, cosmology, and other new experiments.
- ★ Participate in key international groups combining physics results from different experiments. Provide new PDG infrastructure to these groups.
- ★ Innovative features for pdgLive on smart phones, tablets, and laptops.
- ★ Cutting-edge online access to PDG data based on new computing system.
- ★ Publication of enhanced Review of Particle Physics (color figures)
- ★ Developing substantial new features that empower research.
- ★ Continue 56-year pioneering leadership of international Particle Data Group.

# The end

(and extra slides)

**“More than ever before, the RPP is an exceptional achievement that confirms and reinforces its unique role as the central and authoritative source of reference data in particle physics.”**

**“The quality of the work is excellent, meeting the community’s ever-growing expectations.”**

## about pdgLive

- **“This is one of the nicest, clearest, and most useful Web pages in HEP. Superb job.”**
- **“PDG Live is absolutely wonderful. ... Plus, it's really beautiful and lots of fun. I'm so excited I can't even tell you.”**
- **“Bravo! This is the way I always hoped to browse PDG on the web!”**

“Reviewing the proposal for the PDG is somewhat **akin to reviewing motherhood**. The services that have been provided by this group to the world community of high energy physicists is of **inestimable value**. It is carried out with great competence, which accounts for its wide acceptance.”

“The work of the PDG is **absolutely necessary** for rapid progress of elementary particle physics. Without it, the field would be very fragmented and achieving consensus would be very difficult.”

“They have anticipated needs of HEP scientists extremely well. The data provided by the PDG is the best I know about in all fields. Everybody in HEP makes use of the review and many scientists outside HEP.”

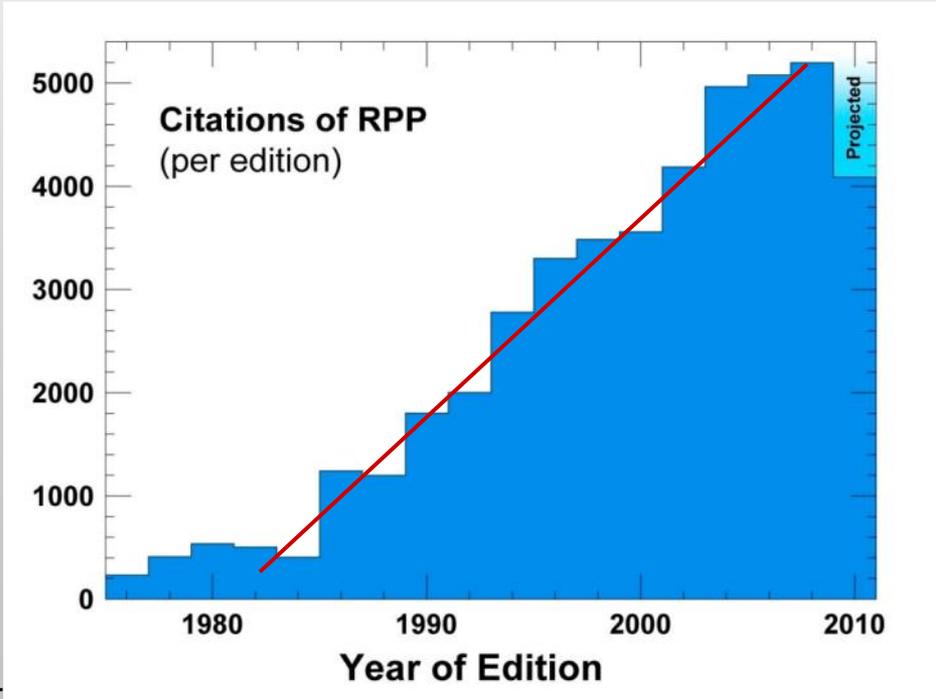
**“It would be hard to imagine HEP without it, and I do not know any other group capable of this effort. The group competence and past accomplishments are excellent.”**

**“The Particle Data Books become "**bibles**" to researchers in particle physics. Without this work, progress would be slower.”**

**... an extremely valuable resource to the particle physics community. This effort is **invaluable** and must be supported. This is constantly being improved and expanded.**

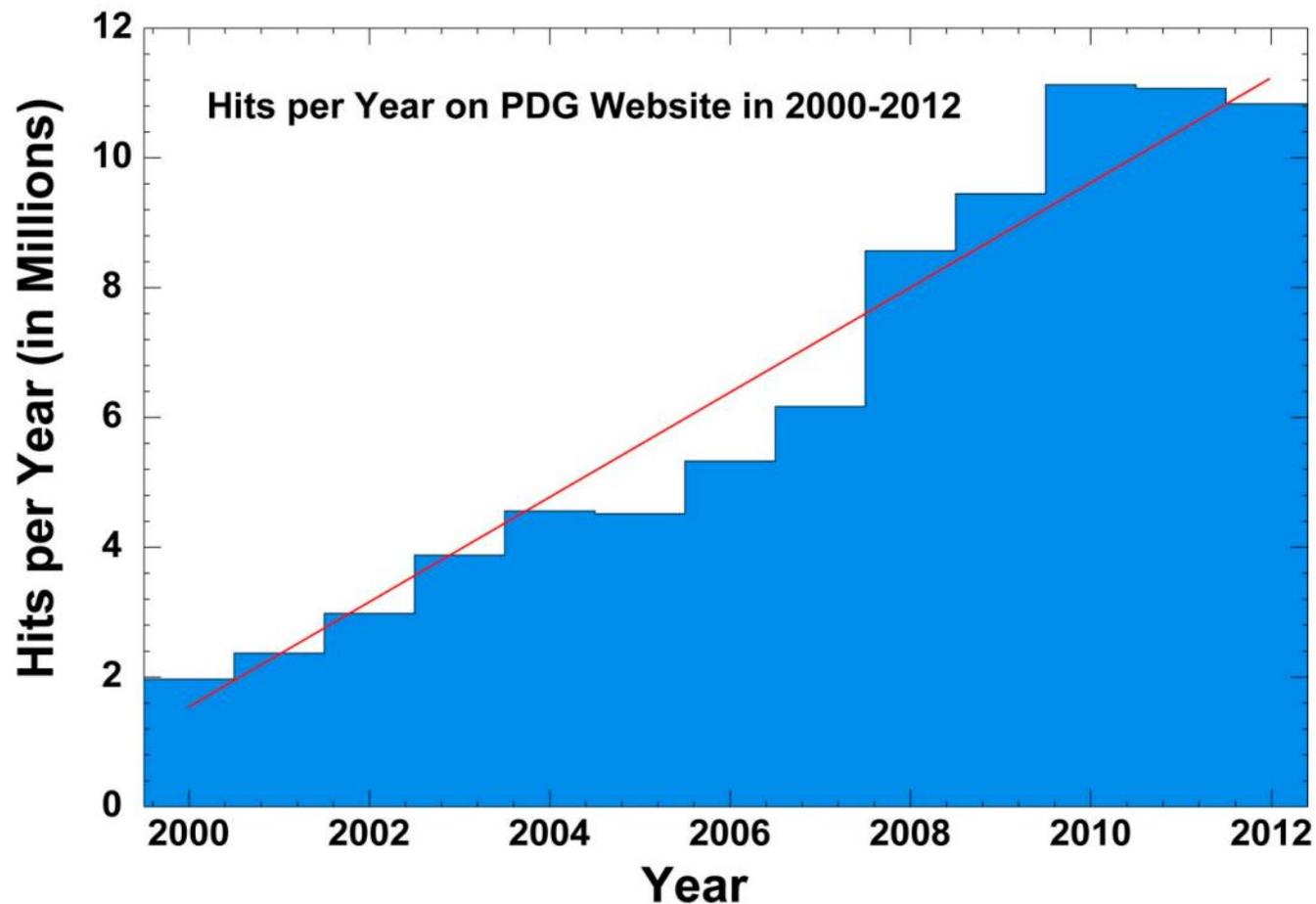
The Review is the all-time top cited article in High Energy Physics with more than **47,000** citations (INSPIRE)

2nd is Weinberg's Standard Model paper with 8359



★ Citations increase for years after an edition is published

Excluding  
mirror sites  
and  
excluding  
education  
webpages



- ***Review of Particle Physics***  
**15,000** copies of 1422-page book
- ***Particle Physics Booklet***  
**31,000** copies of 306-page booklet
- ***Pocket Diary for Physicists***  
**17,000** copies

## Review of Particle Physics

- **Review is a vital and innovative service to the HEP community**
- **Cited by more than 47,000 papers**
- **Webpages receive 11 million hits per year (plus non-LBNL sites)**
- **Improved coverage of neutrinos, B mesons, CP violation, etc.**
- **Improved coverage of Astrophysics/Cosmology**
- **NEW: Powerful Web capabilities**





## Funds from many sources (cash and in-kind)

- NSF
- DOE-HEP
- ATLAS & US-ATLAS
- Michigan State University
- University of Texas, Arlington
- Adler Planetarium, Chicago
- etc.