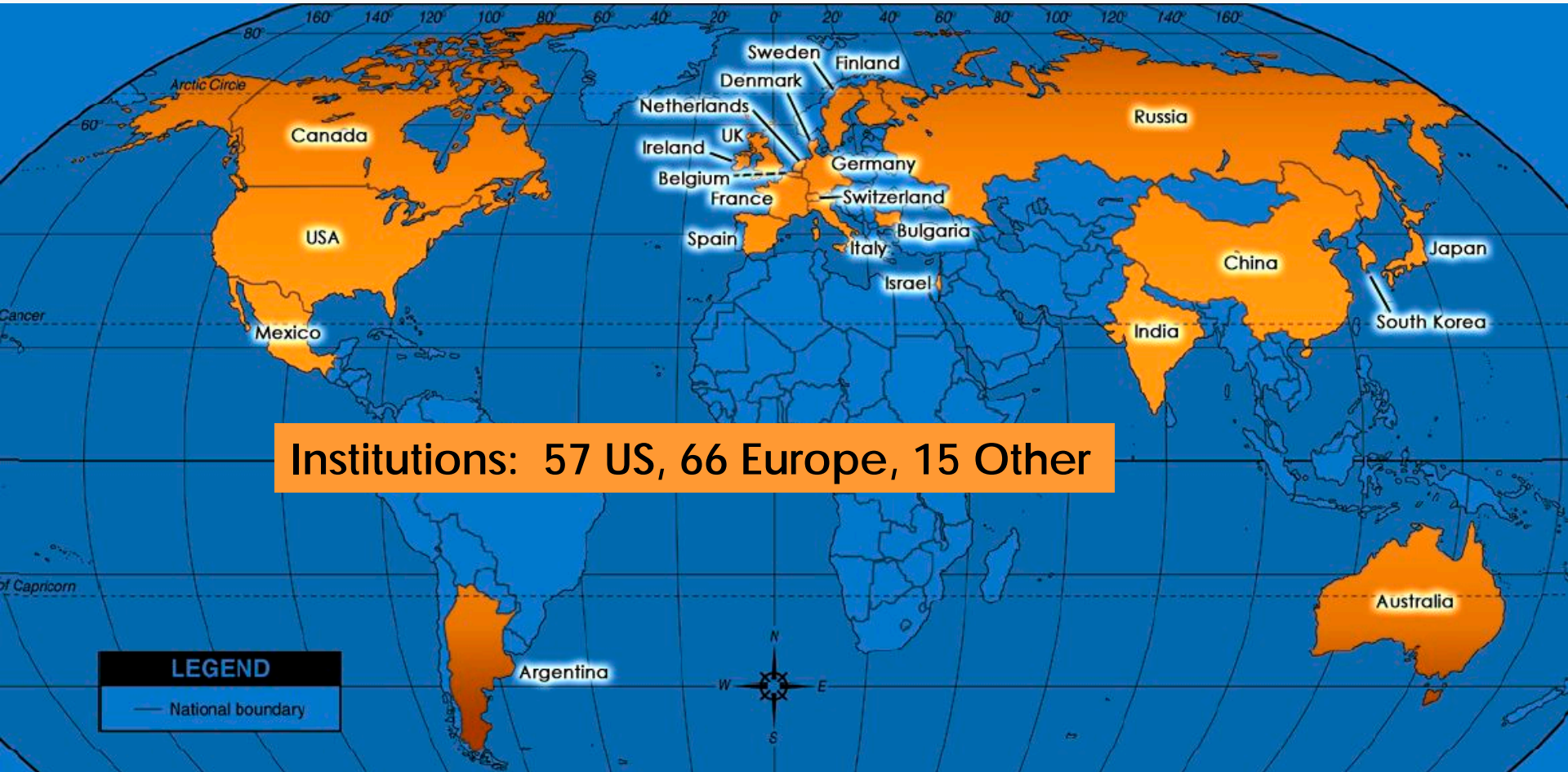


# Particle Data Group

57 years of service

Where PDG is now, and where our community  
wishes us to be in the future

206 authors from 24 countries and 140 institutions



## PDG at LBNL (Central coordination and production)

Physics: 3 FTE's (6 physicists: half PDG and half research)

Editor: physicist

Software developer: physicist

## PDG Collaborators outside of LBNL PDG

196 Physicists from 24 countries (volunteers at 5-10% level).

- Most coordinated directly by LBNL (incl. Japanese Team)
- Meson Resonances Team (Europe) – 13 physicists – semi-indep.
- Baryon Resonances Team (JLab) – 5 physicists – semi-indep.

## PDG Consultants – 700 physicists

- Experiments' Physics Coordinators (etc.) – verifying data listings
- Referees of reviews (3-5 for each review)
- General consultants on content

PDG Users -- tens of thousands

**Clearly this cannot work without vital central coordination.**

# Central Leadership is Essential

Quality control has to be the critical path.  
The community relies on us.



**This requires central coordination.**

With 206 authors, there are many points of failure.  
LBNL's job is to oversee all and make sure  
there is no failure.

## PDG leadership group at LBNL coordinates the entire effort

- Produce and publish the Review
- Handle all of the final checking, editing
- Major contributor to the content
- Choose the authors and the content
- Maintain & drive the schedule
- Coordinate the input of 700 consultants from HEP community
- Assure quality.

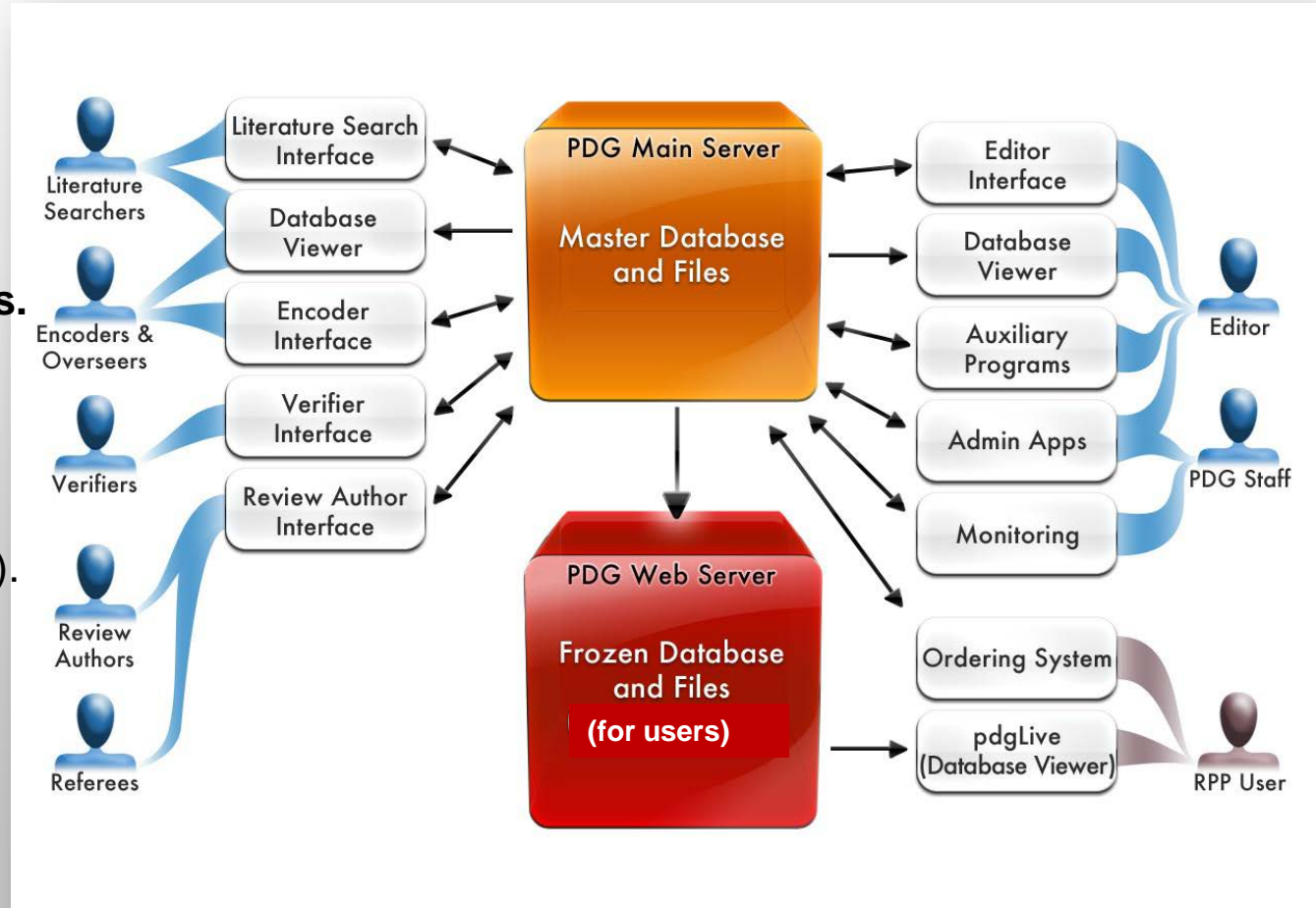
## Essential for

- High-quality
- Timely publication

## Very successful Computing Upgrade completed in Dec. 2011

Enabled many roles:

- **Literature searcher:** 20 journals.
- **Encoder** is world-class expert who interprets papers.
- **Overseer** edits work of encoders.
- **Verifier** is given experiment's physics coordinator (or equiv.).
- **Review authors.**
- **Referees.**
- **Editor.**
- **Etc.**



## PDG Advisory Committee

- Appointed by LBNL Physics Division Director.
- Meets to discuss all aspects of PDG operations.
- Issues detailed report with many recommendations.
- Current committee:

<b>Deborah Harris – Chair</b>	(Fermilab)
<b>James Olsen</b>	(Princeton)
<b>Junichi Tanaka</b>	(U. of Tokyo)
<b>Tancredi Carli</b>	(CERN)
<b>Anze Slosar</b>	(BNL - cosmology)
<b>Yasunori Nomura</b>	(UC Berkeley)



**“The leadership of the PDG has done an excellent job of maintaining and expanding the relevance of the project...**

**The new PDG software has been very successful at producing the data analysis and the web-based interfaces that keep the effort timely, productive and efficient.**

**This is a laudable accomplishment in light of the recent growth in data coming from the new Cosmic Frontier efforts in the field as well as the success of the LHC.”**

# PDG Products

## Review of Particle Physics

### Formats:

#### Printed

- Book – 1675 pages 14k copies
- Booklet – 328 pages 32k copies

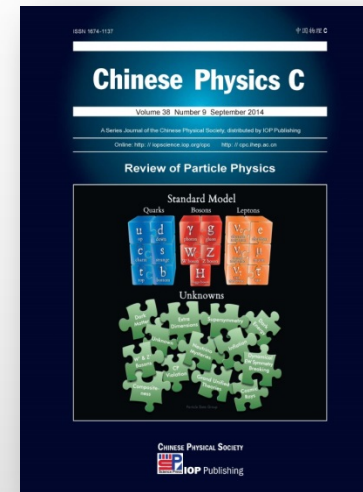
#### Online

- Full content of the book (PDF)
- pdgLive – Interactive database

➔ Detailed and Summarized versions

### Schedule:

- Printed updated in even years.
- Online (including pdgLive) updated once a year.



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

The hits (page views) on

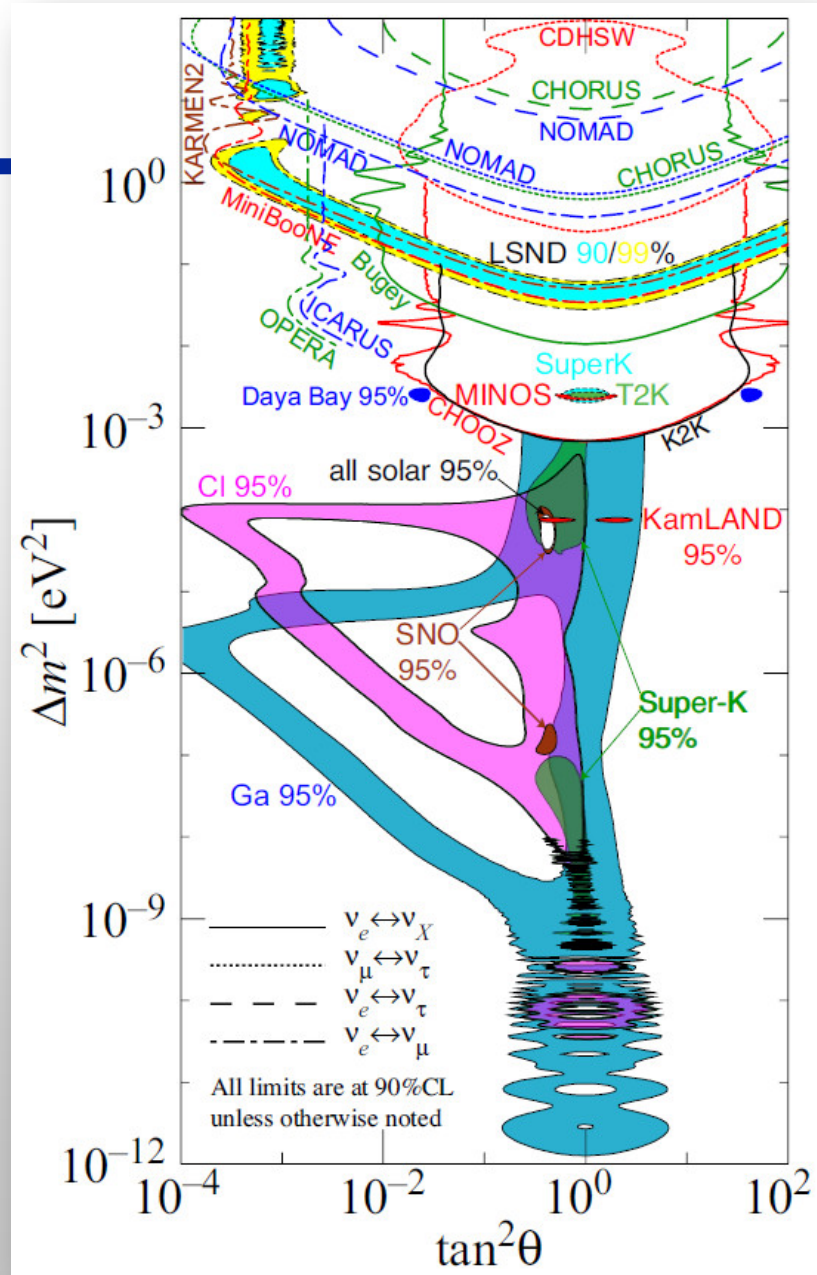
Data Listings = Reviews

almost exactly equal.

Clearly people care about both.

# A Highlight

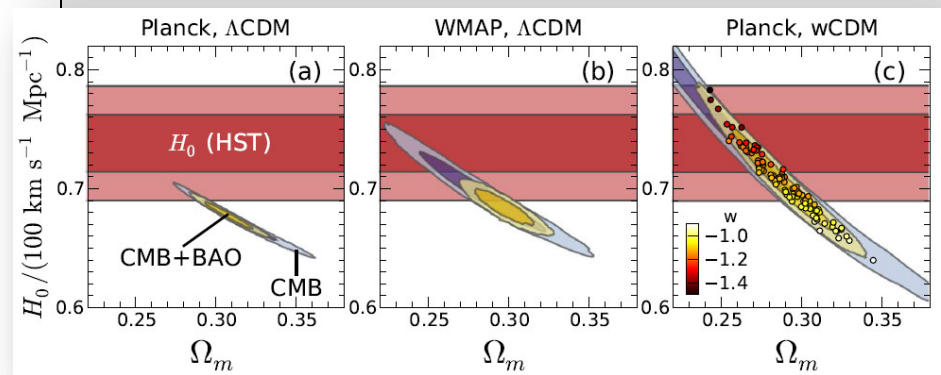
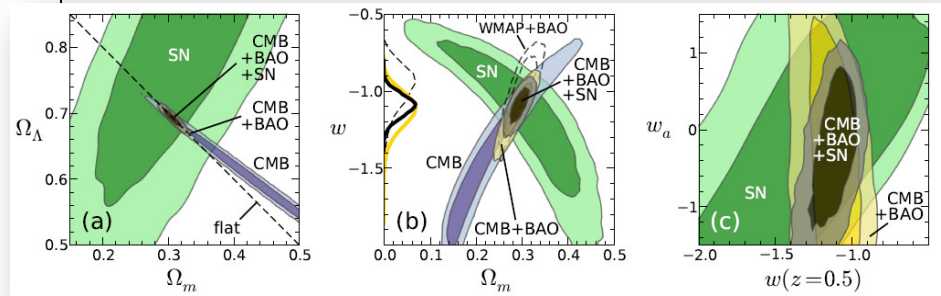
Latest plot shows large mixing of neutrinos



Hitoshi Murayama

Downloads

- Astrophysical Constants** 6091
- Big Bang Cosmology** 7799
- Cosmological Parameters:  
 $H_0$ ,  $\Lambda$ ,  $\Omega$ , etc.** 13769
- Experimental Tests of  
Gravitational Theory** 4234
- Dark Matter** 8591
- Dark Energy** 7627
- Cosmic Background Rad.** 5587
- Big Bang Nucleosynthesis** 4343
- Total Cosmology Downloads** 58,041 (9.4%)



(from Dark Energy review)

138 new papers in 2014 edition (50 in 2012)

## Data Listings split into 3 sections:

- **The  $H^0$  at 125 GeV** (mass, spin,  $\sigma_B$ )
- **Neutral  $H^0$  searches**  
(incl. MSSM  $H_1^0$ ,  $A^0$ , general two-doublet models, fermiophobic, invisible, light  $A^0$ , others)
- **Charged  $H^\pm$  (doublet) and  $H^{\pm\pm}$  (triplet/singlet)**

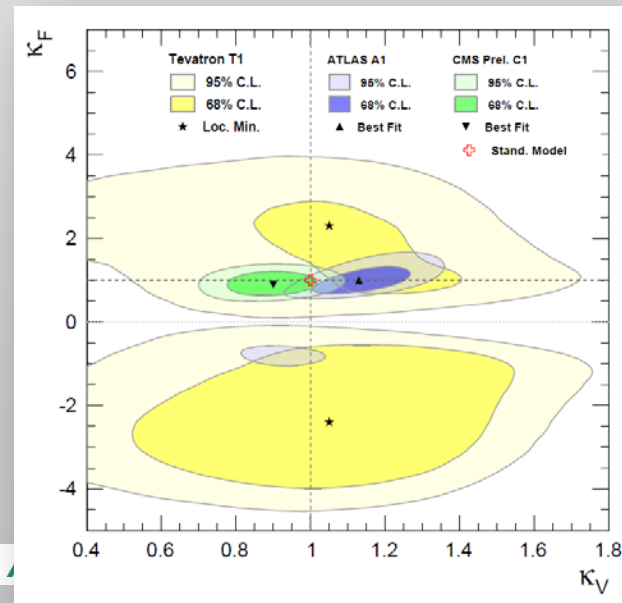
## Review article on Higgs

53 double-column pages

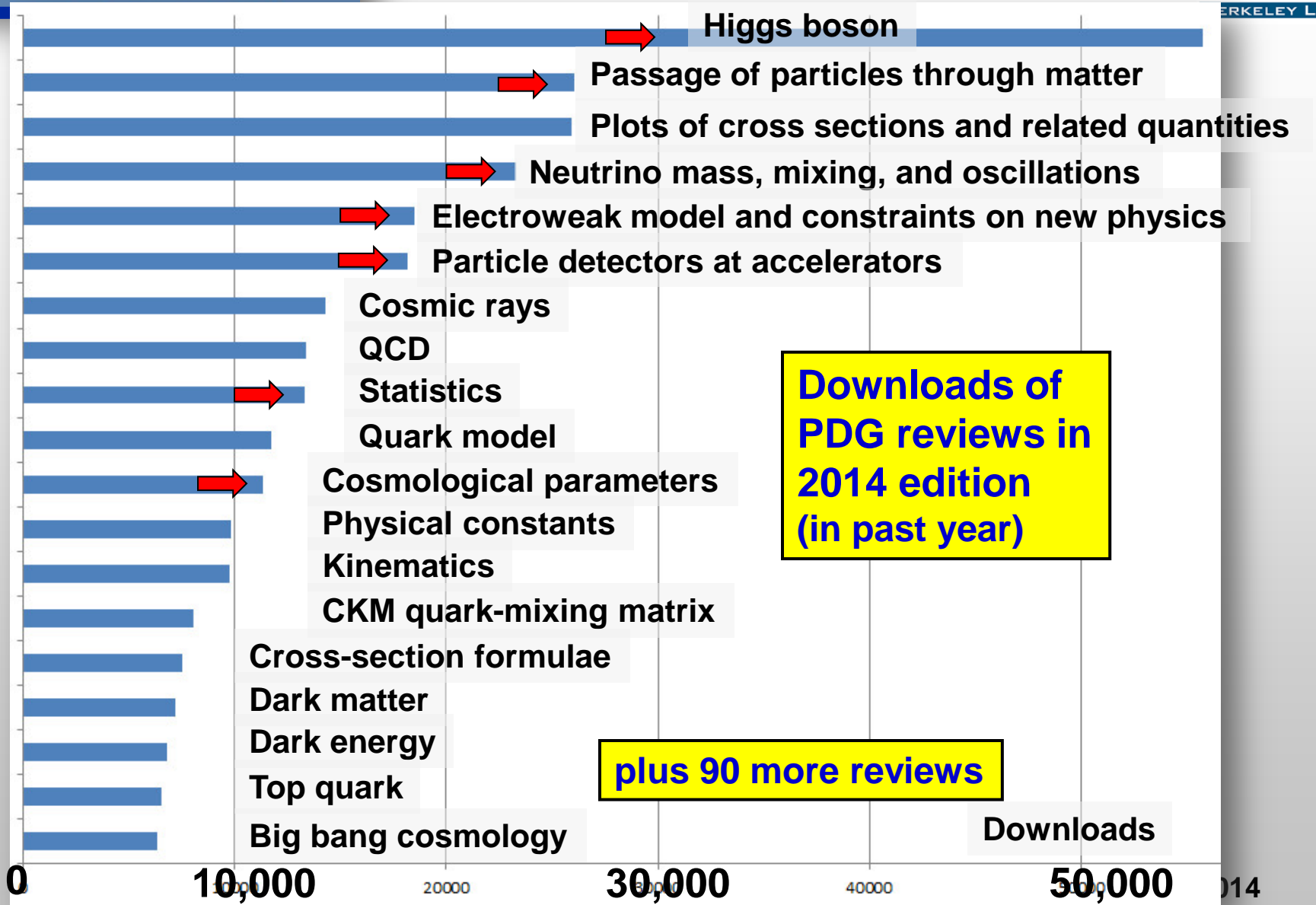
32 figures

18 tables

500 references



# Amazing Diversity of Topics Interest Our Community






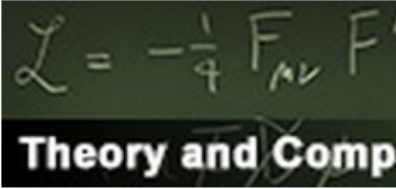


**Downloads of PDG reviews in 2014 edition (in past year)**

**plus 90 more reviews**

Downloads

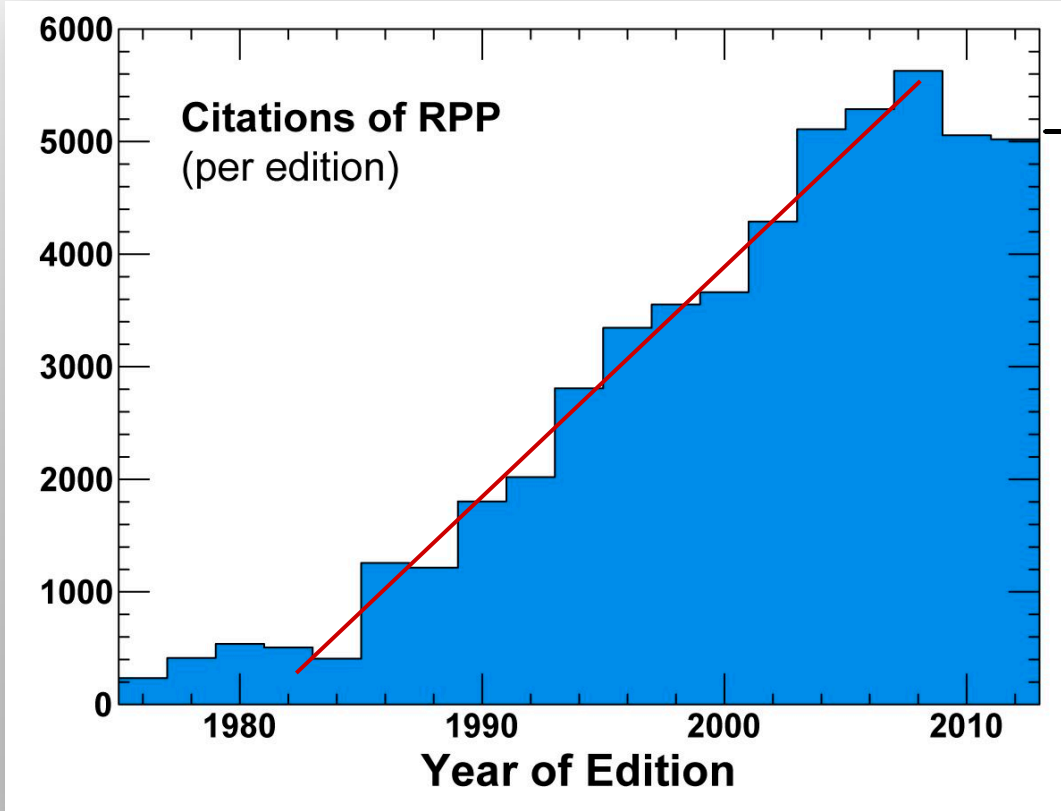


From DOE HEP homepage

 <p><b>Energy Frontier</b></p>	 <p><b>Intensity Frontier</b></p>	 <p><b>Cosmic Frontier</b></p>
 <p><b>Theory and Comp</b></p>	 <p><b>Advanced Techno</b></p>	 <p><b>Accelerator Stewa</b></p>

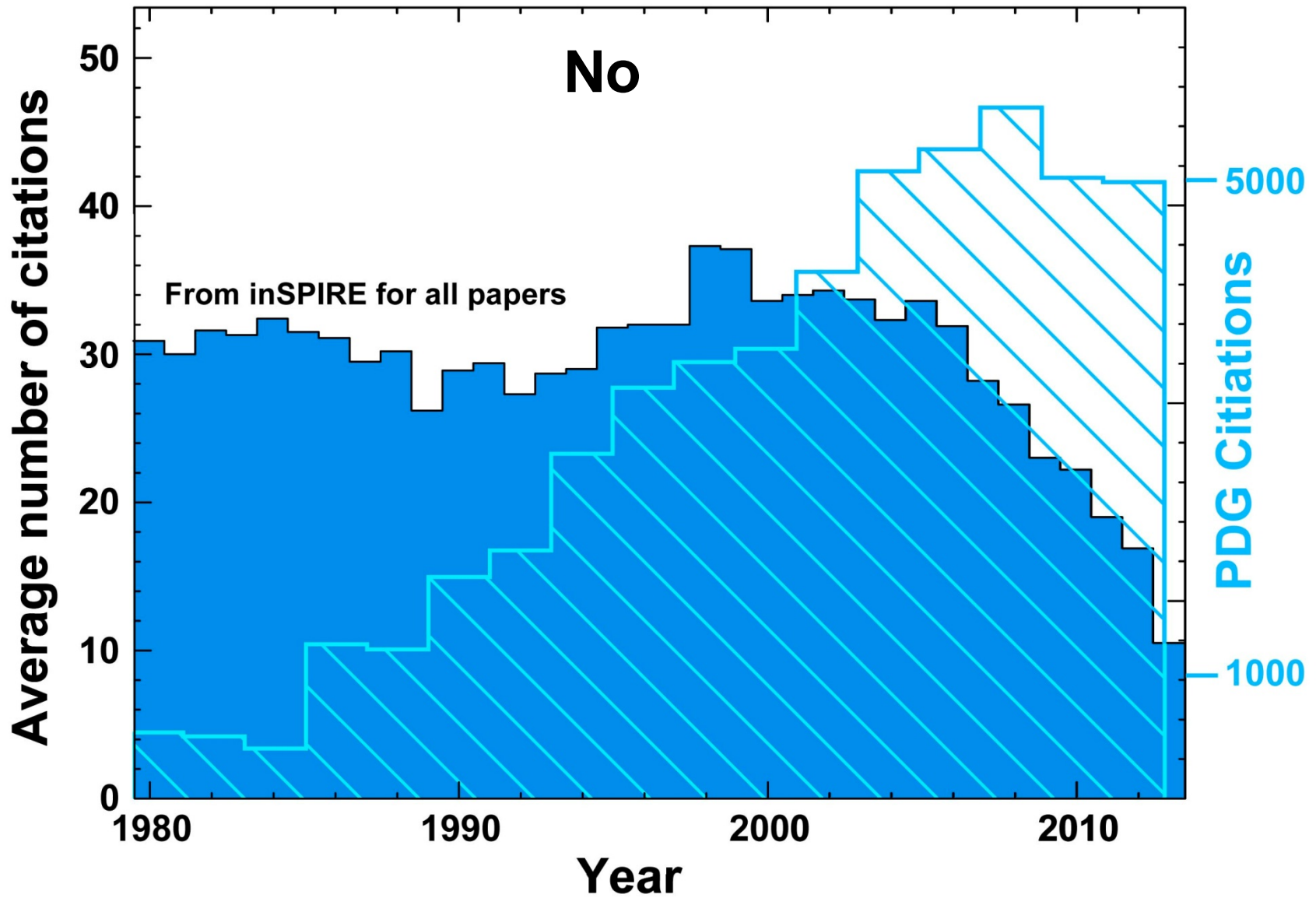
# IMPACT

The Review is the all-time top cited article in High Energy Physics with more than **51,000** citations (INSPIRE)

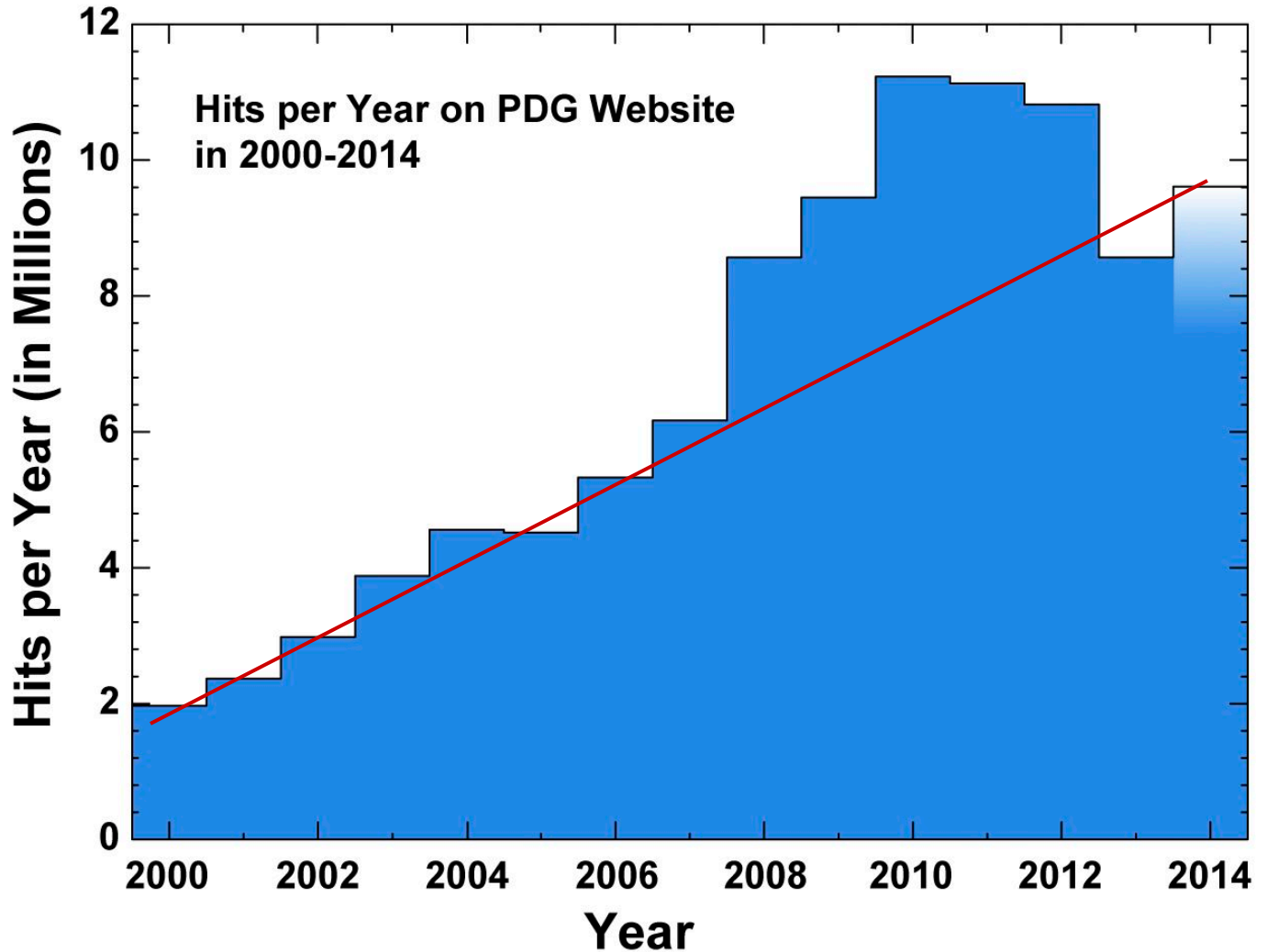


★ Citations increase for years after an edition is published

# Is this just citation inflation?



Excluding  
mirror sites  
and  
excluding  
education  
webpages



# Quality Assurance

**PDG Advisory Committee**

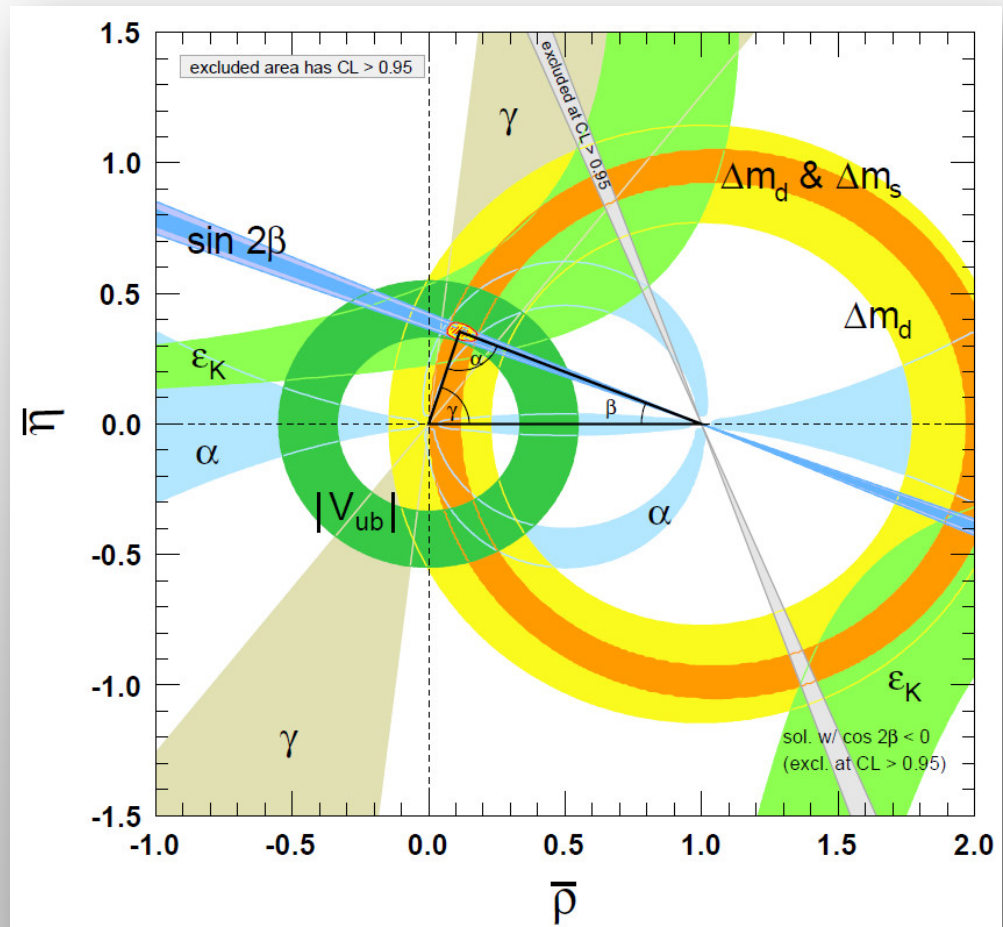
**PDG Workshops**

**Collaboration with Working Groups**

**PDG Research**

## Workshops lead to improved coverage

- Searches
- Neutrino
- CKM
- D Meson
- $\tau$  lepton
- Extra-dimensions
- Statistics





**Coordination with working groups at LHC, Tevatron, B-factories, LEP on:**

- Higgs
- Electroweak fits,
- B lifetimes, B mixing,
- $V_{cb}$  and  $V_{ub}$
- top quark mass, etc.

**Many of these provide fits to our data using PDG guidelines.**

**Research by LBNL PDG members has been recognized as the secret to the success (and quality) of PDG.**

**It is assured that the book is produced by highly qualified active physicists.**

**All are only 50% PDG**

## **LBNL Physicists (ATLAS, Daya Bay, Theory)**

Juerg Beringer  
Dan Dywer  
Cheng-Ju Lin  
Simone Pagan Griso  
Weiming Yao  
Michael Barnett

**“The PDG’s authoritative nature has developed out of a dedication to comprehensive study and evaluation, pursued according to the highest scientific standards.**

**It's modern, immediate, online character has made it an essential daily tool for students and more senior physicists alike.**

**Several reviewers remarked that HEP would be a qualitatively weaker field if the PDG were not there as a current, growing resource.”**

# Issues for PDG

**Moving into electronic era of laptops, tablets and smartphones.**

People are not always online (travel, planes, etc.). **Need apps.**

The book is growing **too big.**

Booklet is **big** for shirt pockets.

Computing system was built for publishing **printed products.**

Computing system still needs to enable new features beyond printed products.

 **Survey on Book, Booklet and App.**

Is having a copy of the full-sized book (booklet) essential to your work or study?

Is a Book without Data Listings OK? (45% as big)  
Is a Booklet without the condensed reviews OK?

How important is an App?

An amazing **6172** readers responded, demonstrating the very high value our community places on PDG products (and **1491** comments).

(We sent out one email; no reminders).

<b>BOOK</b>	<b>BOOKLET</b>	<b>PREFERENCE (in %)</b>
32.1	18.5	Not needed
23.5	18.4	Like but could do without
26.1	29.9	Satisfied with reduced book(let)
18.4	33.2	I need the book(let)

Only 18% say they need full-size book.

82% want the booklet in some form.

**Two thirds** said app was either:  
**Important or Very important.**

**Comments from survey were emphatic:**

**Reduced printed products are dependent on producing replacement app(s).**



- **Summary Tables**  
Basically easy;  
just formatting for readability
- **Review articles**  
Even easier except for formatting tables
- **pdgLive**  
Not easy. Major programming to connect to database and to present on-the-fly.  
Proposal to DOE to do this.



**Issue with Book is cost and the size and eventual binding issues.** (Summary Tables, Reviews and Listings grow every edition).

**Five publishers bid on Book and Booklet in past**  
(PL, PR, J. Phys., Eur. Phys., Chin. Phys.)

**This year, with essentially no funds to pay for them, one publisher bid on RPP and Booklet:**

**Chinese Physics C, at about 8% of their actual cost.**



Slow boat from China

Discussed by Collaboration and Advisory Committee

## Book:

- a) **Keep book as is** (Where is funding?  
How control size to avoid binding issues?)
- b) **Discontinue** (Not the preference of 68%)

## Conclusion:

- c) **Reduce content & size to 40-45%** (no data listings)  
Still some cost, perhaps \$80,000 (LBNL share).

Issue with Booklet is not cost (paid by CERN)

It is: **the number of pages and eventual binding issues.**

Summary Tables grow every edition

## Booklet:

- a) **Discontinue** (Not the preference of 82%)
- b) **Reduce content & size** (Which content? How satisfy readers?).

## Conclusion:

- c) **Keep booklet as is** – Not urgent decision, so postpone decision for two years (when app is available).

# Assuring the Future

**“... the age of ink marks on dead tree carcasses is over.”**

(Comment from 2014 PDG Survey)



“Nevertheless, keep some hard copies around for after the next big **solar flare**....”

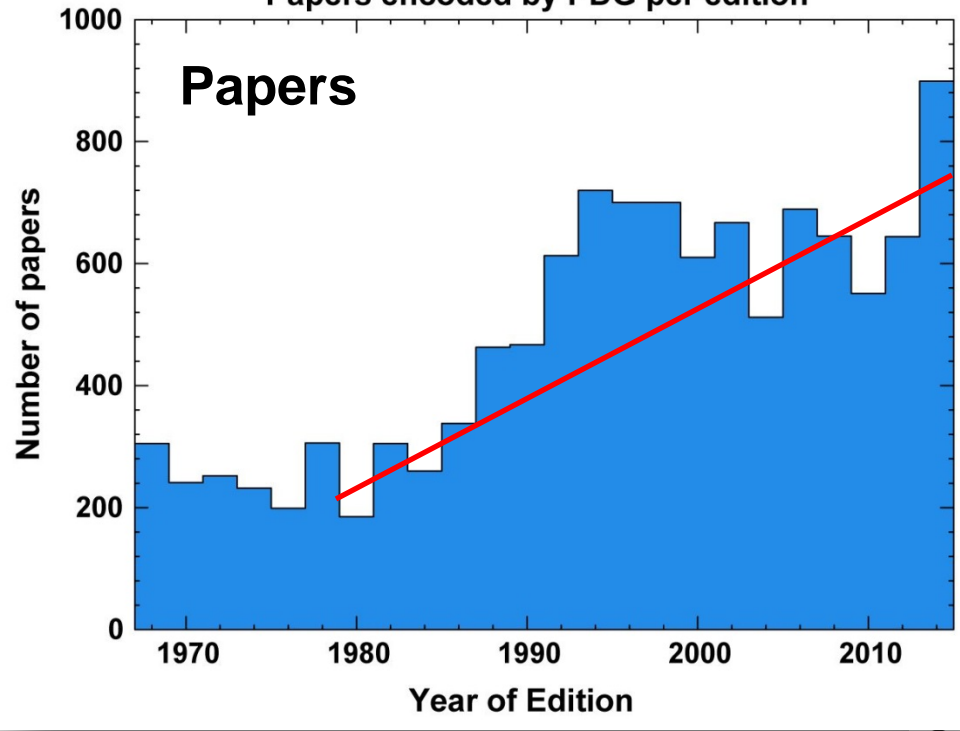
- **Books and booklet will still be in demand for some time**
- **Demand increasing for electronic distribution, including:**
  - Static web pages and PDF files
  - Dynamic web pages (pdgLive - many extensions possible)
  - E-books
  - App(s) for smartphones and tablets (all platforms)
  - API (access to PDG database by programs)
  - Downloadable PDG data (use of our data by others in their apps etc)
  - ...

- Emphasis on searching and indexing, rather than navigation
- Cross-linking with other services (pdgLive ↔ INSPIRE available)
- pdgLive version for offline use (as an app)
- Interactive plotting, data selection and evaluation
- Interactive presentation of review articles
- User tagging or display of contributed content

**Implementing some of these new features is a long-term effort given our very limited resources**

# Workload and Budget Issues

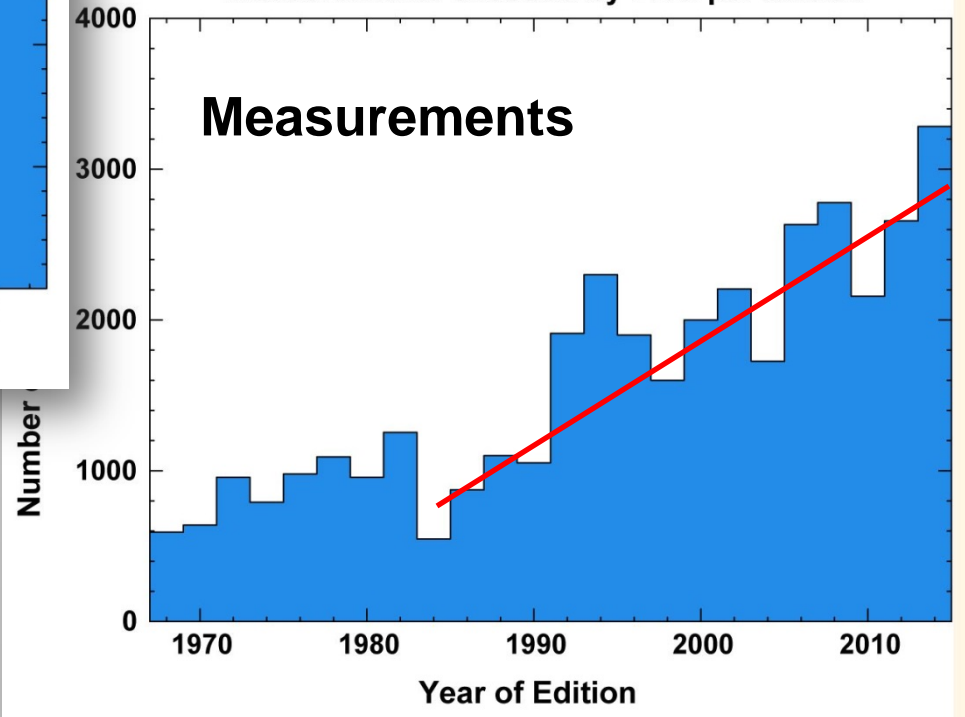
Papers encoded by PDG per edition



**LHC bump**

Some editions are more or less than 24 months, yielding fluctuations in graphs.

Measurements encoded by PDG per edition



So there is an increasing burden on the LBNL group.

<u>Papers</u>	<u>2008</u>	<u>2010</u>	<u>2012</u>	<u>2014</u>
Supersymmetry	33	34	68	123
Axions	18	21	21	36
Higgs	12	34	51	138
W', Z'	18	16	36	50
Compositeness	6	5	12	17
Extra dimensions	11	10	17	32
Other searches	4	12	37	94
Free q, monopoles	1	3	2	6
	<b>103</b>	<b>135</b>	<b>244</b>	<b>496</b> ←

132 → 120 → **183** B papers in 2010, 2012, **2014** editions

**The success of PDG over many years has been due to the generous support of DOE, NSF, Japan and CERN.**

**Current funding from DOE + Japan (Japan 6%)**

**NSF grant (12% of budget) ended last year (after 30 years)**

**DOE initial guidance during CR, 11% budget cut.**

**CERN in-kind funding.** Covers products shipped to CERN and distributed throughout Europe. Funds Meson Team expenses. Pays all printing costs for Booklet.

**The ability of PDG to meet future needs depends on adequate funding.**

**The PDG budget is essentially salary only.**

**Handled recent budget cuts by:**

- **Phased out rehired-retirees.**
- **Replaced our full-time admin with a 10% admin.**
- **Pocket Diary for Physicists eliminated.**
- **All printed products are not currently in our budget.**  
(One-time savings with Chinese publication).

**Successful operation requires stable funding at constant level of effort.**

**Reduced book may be about \$80,000 (every other year).**

**Not in current budget.**






**To develop interactive app (like pdgLive)**

**on one-time basis of about 0.25 FTE in FY15 and  
0.25 FTE in FY16.**

**Then cost each year is about \$80,000 per year.**

**Not in current budget.**



-  **32,000 Booklets requested**
-  **14,000 RPP books requested**
-  **10 million hits/year on website (>180 countries)**
-  **51,000 citations of RPP**
-  **Most cited publication in HEP**

**PDG provides a vital, dynamic, innovative service to the HEP community.**

**The HEP community depends on PDG to provide standards and to assure integrity and quality in summarizing particle physics.**

**The End**



## 899 new papers with 3283 new measurements.

330 LHC papers: ATLAS, CMS, and LHCb

Extensive Higgs boson coverage from 138 papers with 258 measurements.

Supersymmetry: 123 papers with major exclusions, many from LHC experiments.

Latest from B-meson physics: 183 papers with 803 measurements, including first observation of  $B_s \rightarrow \mu^+\mu^-$  from LHCb and CMS.

Cosmology reviews updated to include 2013 Planck.

Updated and new results in neutrino mixing on  $\Delta m^2$  and mixing angle measurements, including the first  $\Delta m_{32}^2$  from reactor experiment.

72 new top results since 2012, many from LHC experiments.

Final assignment of  $1^{++}$  quantum numbers to the X(3872) by LHCb.

Observation of charmonium-like states X(3900) and X(4020) (BESIII and BES3).

Observation of bottomonium-like states X(10620) and X(10650) (Belle).

Heavily revised Atomic- Nuclear Properties website.

## New reviews on:

- Higgs Boson Physics
- Dark Energy
- Monte Carlo Neutrino Generators
- Resonances

## Significant update/revision to reviews on:

- Top Quark
- Dynamical Electroweak Symmetry Breaking
- Astrophysical Constants
- Dark Matter
- Big-Bang Nucleosynthesis
- Neutrino Cross Section Measurements
- Accelerator Physics of Colliders
- High-Energy Collider Parameters
- Total Hadronic Cross Sections Plots

# B Meson Section 1984

Entire section was one page

## $B^\pm, B^0, B$

### $B^\pm$

41 CHARGED B(5271, JP= ) I=

SEE ALSO THE LISTING FOR THE B (FOLLOWING THE ENTRY FOR THE NEUTRAL B) FOR MEASUREMENTS WHICH DO NOT IDENTIFY THE CHARGE STATE.

#### 41 CHARGED B MASS (MEV)

M	A	6	5270.8	3.0	BEHREND	83	CLEO	--	D* <sup>-</sup>	PI <sup>+</sup>	PI <sup>+</sup>	+ CC	4/83*
M	A												4/83*

STATISTICAL (2.3 MEV) AND SYSTEMATICAL (2.0 MEV) ERRORS COMBINED.

#### 41 CHARGED B PARTIAL DECAY MODES

P1	B <sup>+</sup>	INTO	D0BAR	PI <sup>+</sup>	DECAY MASSES
P2	B <sup>+</sup>	INTO	D*(2010) <sup>-</sup>	PI <sup>+</sup>	1865+ 140
					2007+ 140+ 140

B<sup>-</sup> MODES ARE CHARGE CONJUGATES OF THE ABOVE MODES.

#### 41 CHARGED B BRANCHING RATIOS

R1	B <sup>+</sup>	INTO	D0BAR	PI <sup>+</sup>	0.042	0.042	BEHREND	83	CLEO	--	E <sup>+</sup>	E <sup>-</sup>	, UPSIL(4S)	4/83*
R1														
R2	B <sup>+</sup>	INTO	D*(2010) <sup>-</sup>	PI <sup>+</sup>	0.048	0.030	BEHREND	83	CLEO	--	E <sup>+</sup>	E <sup>-</sup>	, UPSIL(4S)	4/83*
R2														

#### REFERENCES FOR CHARGED B

BEHREND 83 PRL 50 881 + (ROCH+RUTG+SYRA+VAND+CORN+ITHA+NARY+OSU)

### $B^0$

42 NEUTRAL B(5274, JP= ) I=

SEE ALSO THE LISTING FOR THE B (FOLLOWING THIS ENTRY) FOR MEASUREMENTS WHICH DO NOT IDENTIFY THE CHARGE STATE.

#### 42 NEUTRAL B MASS (MEV)

M	A	5	5274.2	2.8	BEHREND	83	CLEO	0	D* <sup>-</sup>	PI <sup>+</sup>	+ CC	4/83*
M	A											4/83*

STATISTICAL (1.9 MEV) AND SYSTEMATICAL (2.0 MEV) ERRORS COMBINED.

#### 42 (B0) - (B+) MASS DIFFERENCE (MEV)

DM	A		3.4	3.6	BEHREND	83	CLEO		E <sup>+</sup>	E <sup>-</sup>	, UPSIL(4S)	3/84*
DM	A											3/84*

STATISTICAL (3.0) AND SYSTEMATICAL (2.0) ERRORS COMBINED.

#### 39 B PARTIAL DECAY M

P1	B	INTO	ELECTRON	NEUTRINO	HADRONS
P2	B	INTO	MUON	NEUTRINO	HADRONS
P3	B	INTO	E <sup>+</sup>	E <sup>-</sup>	ANYTHING
P4	B	INTO	MU <sup>+</sup>	MU <sup>-</sup>	ANYTHING
P5	B	INTO	KAON	ANYTHING	
P6	B	INTO	J/PSI	ANYTHING	
P7	B	INTO	DO	ANYTHING	
P8	B	INTO	PROTON	ANYTHING	
P9	B	INTO	LAMBDA	ANYTHING	

#### 39 B BRANCHING RATIO

R1	B	INTO	(ELECTRON	NEUTRINO	HADRONS)
R1			(0.13)	(0.042)	BEB
R1	B		(0.136)	(0.039)	SPE
R1	C		0.127	0.021	CHA
R1	D		0.132	0.016	KLO
R1	E		(0.116)	(0.027)	NEL
R1	A	THE	STATISTICAL	AND	SYSTEMATIC
R1	B	THE	STATISTICAL	AND	SYSTEMATIC
R1	AB	THE	ELECTRON	ENERGY	SPECTRA
R1	AB	B-TO-C	OVER	B-TO-U	QUARK
R1	C	THE	STATISTICAL	AND	SYSTEMATIC
R1	D	STATISTICAL	AND	SYSTEMATIC	ERRORS
R1	D	RATIO	CS(B-->E	NU UP)/CS(B-->E	NU
R1	E	THE	STATISTICAL	AND	SYSTEMATIC
R1					
R1					ONLY
R1					THE
R1					EXPERIMENTS
R1					AT
R1					THE
R1	AVG		0.130	0.013	AVERAGE

R2	B	INTO	(MUON	NEUTRINO	HADRONS)/TOT
R2			(0.094)	(0.036)	CHA
R2	A		(0.105)	(0.020)	ADE
R2	B		0.124	0.035	CHA
R2			(0.155)	(0.054)	(0.029)
R2			(0.117)	(0.028)	ALT
R2	A	THE	STATISTICAL	AND	SYSTEMATIC
R2	B	THE	STATISTICAL	AND	SYSTEMATIC
R2					
R2					THE
R2					AVERAGE
R2					OF
R2					THE
R2					THREE
R2					HIGH-ENE
R2					THESE
R2					EXPERIMENTS
R2					PRODUCE
R2					OTHER
R2					B
R2					THE
R2					B
R2					MESON.
R3	B	INTO	(E <sup>+</sup>	E <sup>-</sup>	ANYTHING)/TOTAL
R3			(0.05)	OR	LESS
R3					CL=.90
R3					BEB
R4	B	INTO	(MU <sup>+</sup>	MU <sup>-</sup>	ANYTHING)/TOTAL
R4			(0.017)	OR	LESS
R4					CL=.90
R4			0.007	OR	LESS
R4					CL=.95
R4			0.007	OR	LESS
R4					CL=.95
R4			(0.02)	OR	LESS
R4					CL=.95
R4					ALT
R5	B	INTO	(DILEPTON	ANYTHING)	

Section  
is 198  
pages.

In 2008  
was 144  
pages

## BOTTOM, CHARMED MESONS ( $B = C = \pm 1$ )

$$B_c^+ = c\bar{b}, B_c^- = \bar{c}b, \text{ similarly for } B_c^{*+}$$

 $B_c^\pm$ 

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

$I, J, P$  need confirmation.

Quantum numbers shown are quark-model predictions.

### $B_c^\pm$ MASS

VALUE (GeV)	DOCUMENT ID	TECN	COMMENT
<b>6.2756 ± 0.0011 OUR AVERAGE</b>			
6.27628 ± 0.00144 ± 0.00036	<sup>1</sup> AAIJ	13AS LHCb	$pp$ at 7, 8 TeV
6.2737 ± 0.0013 ± 0.0016	<sup>2</sup> AAIJ	12AV LHCb	$pp$ at 7 TeV
6.2756 ± 0.0029 ± 0.0025	<sup>3</sup> AALTONEN	08M CDF	$p\bar{p}$ at 1.96 TeV
6.300 ± 0.014 ± 0.005	<sup>3</sup> ABAZOV	08T D0	$p\bar{p}$ at 1.96 TeV
6.4 ± 0.39 ± 0.13	<sup>4</sup> ABE	98M CDF	$p\bar{p}$ at 1.8 TeV
6.2857 ± 0.0053 ± 0.0012	<sup>3</sup> ABULENCIA	06C CDF	Repl. by AALTONEN 08M
6.32 ± 0.06	<sup>5</sup> ACKERSTAFF	98O OPAL	$e^+e^- \rightarrow Z$

- • • We do not use the following data for averages, fits, limits, etc. • • •
- <sup>1</sup> AAIJ 13AS uses the  $B_c^+ \rightarrow J/\psi D_S^+$ .
- <sup>2</sup> AAIJ 12AV uses the  $B_c^+ \rightarrow J/\psi \pi^+$  mode and also measures the mass difference  $M(B_c^+) - M(B^+) = 994.6 \pm 1.3 \pm 0.6 \text{ MeV}/c^2$ .
- <sup>3</sup> Measured using a fully reconstructed decay mode of  $B_c \rightarrow J/\psi \pi$ .
- <sup>4</sup> ABE 98M observed  $20.4^{+6.2}_{-5.5}$  events in the  $B_c^+ \rightarrow J/\psi(1S) \ell \nu_\ell$  with a significance of  $> 4.8$  standard deviations. The mass value is estimated from  $m(J/\psi(1S) \ell)$ .
- <sup>5</sup> ACKERSTAFF 98O observed 2 candidate events in the  $B_c^+ \rightarrow J/\psi(1S) \pi^+$  channel with an estimated background of  $0.63 \pm 0.20$  events.

### $B_c^\pm$ MEAN LIFE

"OUR EVALUATION" is an average using rescaled values of the data listed below. The average and rescaling were performed by the Heavy Flavor Averaging Group (HFAG) and are described at <http://www.slac.stanford.edu/xorg/hfag/>. The averaging/rescaling procedure takes into account correlations between the measurements.

VALUE ( $10^{-12}$ s)	DOCUMENT ID	TECN	COMMENT
<b>0.452 ± 0.033 OUR EVALUATION</b>			
<b>0.500 ± 0.013 OUR AVERAGE</b>			
0.509 ± 0.008 ± 0.012	<sup>6</sup> AAIJ	14G LHCb	$pp$ at 8 TeV
0.452 ± 0.048 ± 0.037	<sup>7</sup> AALTONEN	13 CDF	$p\bar{p}$ at 1.96 TeV

$\Gamma_{11}$	$D^+ K^{*0}$	$< 0.20$
$\Gamma_{12}$	$D^+ \bar{K}^{*0}$	$< 0.16$
$\Gamma_{13}$	$D_s^+ K^{*0}$	$< 0.28$
$\Gamma_{14}$	$D_s^+ \bar{K}^{*0}$	$< 0.4$
$\Gamma_{15}$	$D_s^+ \phi$	$< 0.32$
$\Gamma_{16}$	$K^+ K^0$	$< 4.6$
$\Gamma_{17}$	$B_S^0 \pi^+ / B(\bar{b} \rightarrow B_S)$	$(2.37^{+0.}_{-0.})$

### $B_c^+$ BRANCHING RATIOS

#### $\Gamma(J/\psi(1S) \ell^+ \nu_\ell \text{ anything}) / \Gamma_{\text{total}} \times B(\bar{b} \rightarrow B_c)$

VALUE	CL%	DOCUMENT ID	TECN
$(5.2^{+2.4}_{-2.1}) \times 10^{-5}$		<sup>9</sup> ABE	98M CDF

- • • We do not use the following data for averages, fits, limits
- $< 1.6 \times 10^{-4}$  90 <sup>10</sup> ACKERSTAFF 98O OPAL
- $< 1.9 \times 10^{-4}$  90 <sup>11</sup> ABREU 97E DLPHI
- $< 1.2 \times 10^{-4}$  90 <sup>12</sup> BARATE 97H ALEPH
- <sup>9</sup> ABE 98M result is derived from the measurement of  $[\sigma(B_c) \times B(B^+) \times B(B^+ \rightarrow J/\psi(1S) K^+)] = 0.132^{+0.041}_{-0.037} (\text{stat})$  by using PDG 98 values of  $B(b \rightarrow B^+)$  and  $B(B^+ \rightarrow J/\psi K^+)$ .
- <sup>10</sup> ACKERSTAFF 98O reports  $B(Z \rightarrow B_c X) / B(Z \rightarrow qq) \times 6.95 \times 10^{-5}$  at 90%CL. We rescale to our PDG 98 values of  $B(b \rightarrow B^+)$ .
- <sup>11</sup> ABREU 97E value listed is for an assumed  $\tau_{B_c} = 0.4 \text{ ps}$  and  $\tau_{B_c} = 1.4 \text{ ps}$ .
- <sup>12</sup> BARATE 97H reports  $B(Z \rightarrow B_c X) / B(Z \rightarrow qq) \times B(B_c \rightarrow \text{anything}) = 6.95 \times 10^{-5}$  at 90%CL. We rescale to our PDG 96 values of  $B(Z \rightarrow b\bar{b})$ . candidate event is found, compared to all the known background which gives  $m_{B_c} = 5.96^{+0.25}_{-0.19} \text{ GeV}$  and  $\tau_{B_c} = 1.77 \pm 0.17 \text{ ps}$ .

#### $\Gamma(J/\psi(1S) \pi^+) / \Gamma_{\text{total}} \times B(\bar{b} \rightarrow B_c)$

VALUE	CL%	DOCUMENT ID	TECN
seen		AALTONEN	13 CDF
seen		<sup>13</sup> AAIJ	12AV LHCb
seen		AALTONEN	08M CDF
seen		ABAZOV	08T D0

- • • We do not use the following data for averages, fits, limits
- $< 2.4 \times 10^{-4}$  90 <sup>14</sup> ACKERSTAFF 98O OPAL
- $< 3.4 \times 10^{-4}$  90 <sup>15</sup> ABREU 97E DLPHI
- $< 8.2 \times 10^{-5}$  90 <sup>16</sup> BARATE 97H ALEPH
- $< 2.0 \times 10^{-5}$  95 <sup>17</sup> ABE 96R CDF
- <sup>13</sup> AAIJ 12AV reports a measurement of  $B(B_c^+ \rightarrow J/\psi \pi^+) / B(B_c^+ \rightarrow \text{anything}) = (0.68 \pm 0.10 \pm 0.03 \pm 0.05)\%$  at  $p_T(B_c) > 4 \text{ GeV}$  and 2.5
- <sup>14</sup> ACKERSTAFF 98O reports  $B(Z \rightarrow B_c X) / B(Z \rightarrow qq) \times$