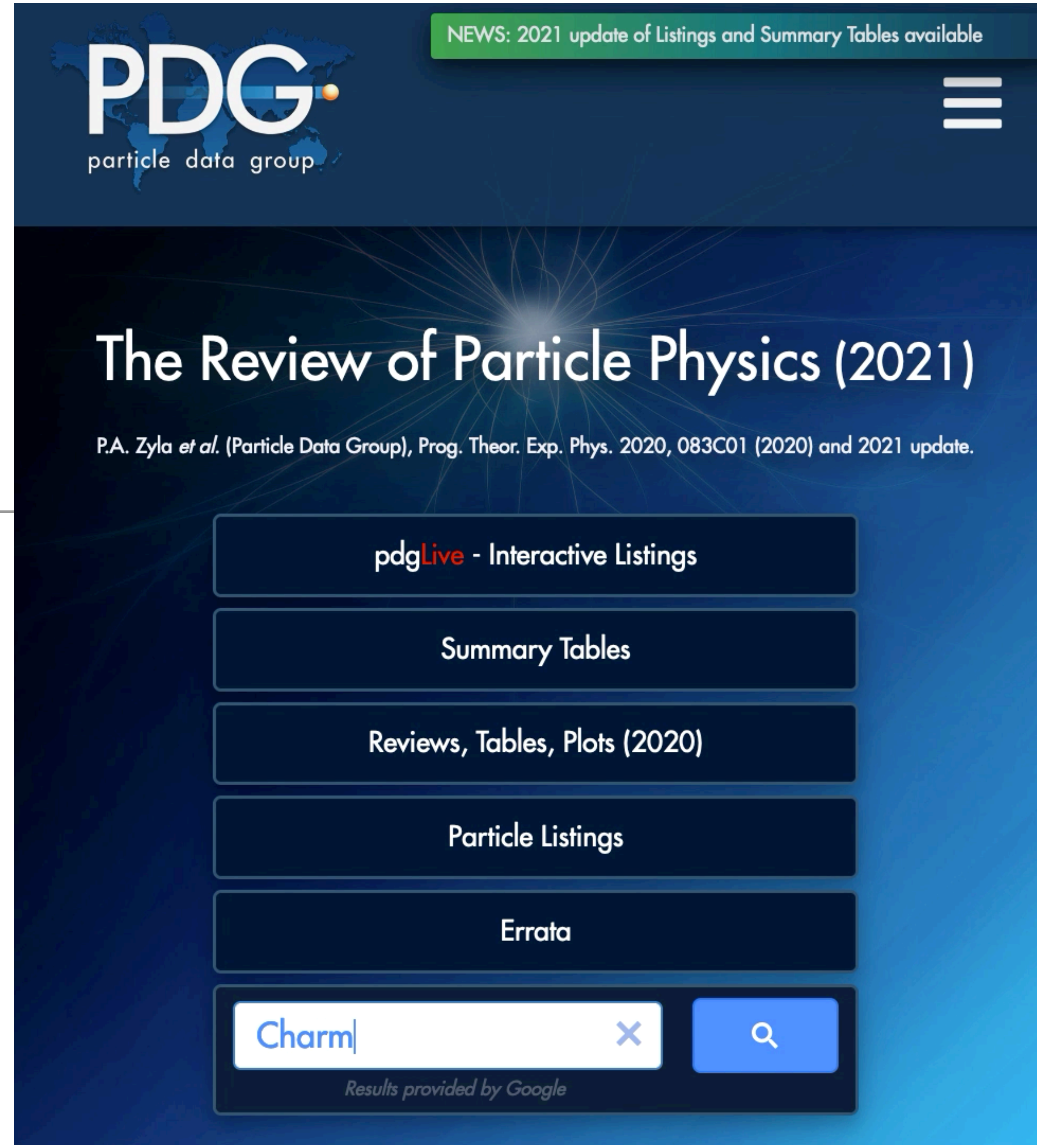
PDG view on Charm

Jonas Rademacker
(University of Bristol)
for the Particle Data Group

CHARM 2021



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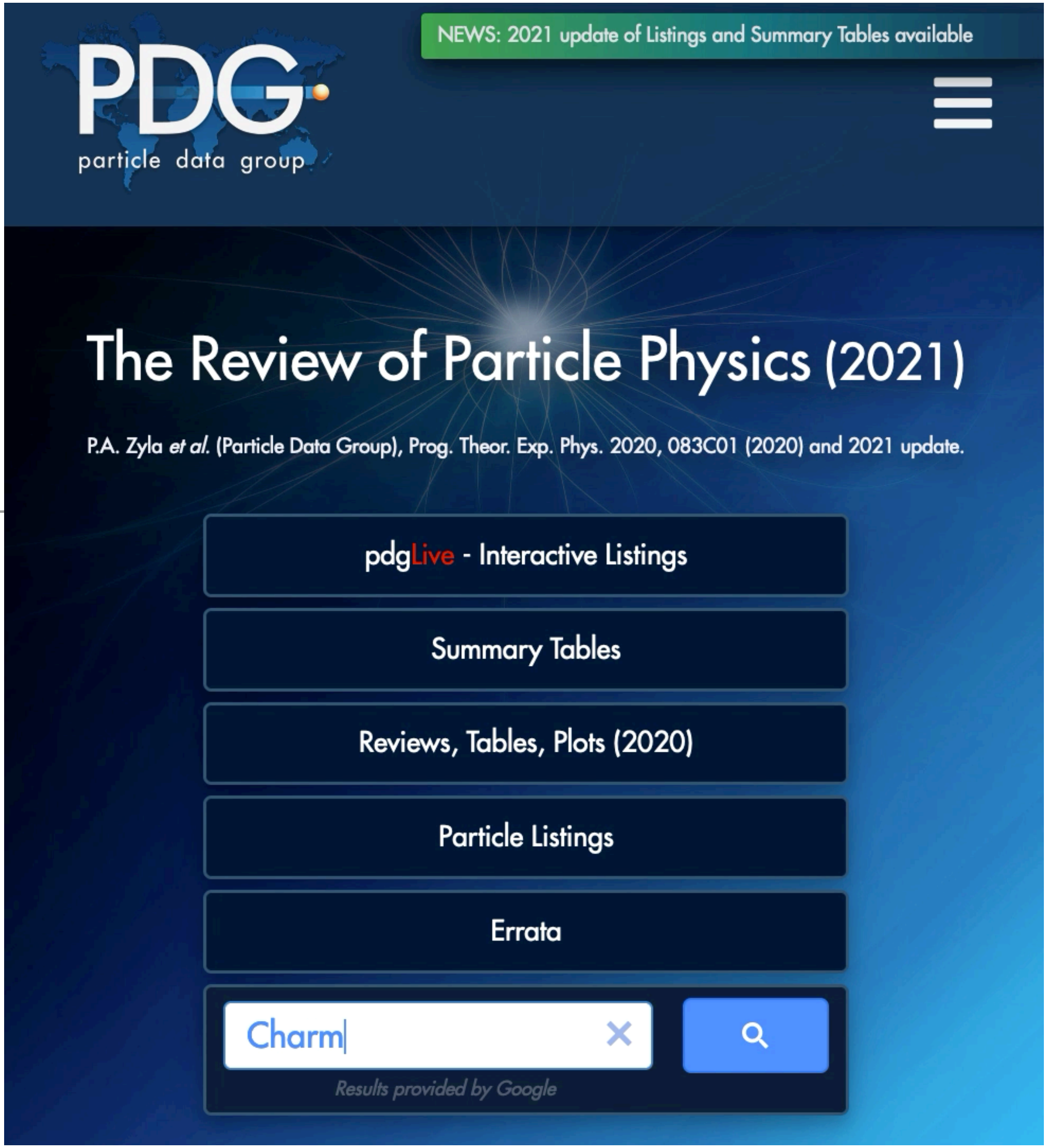
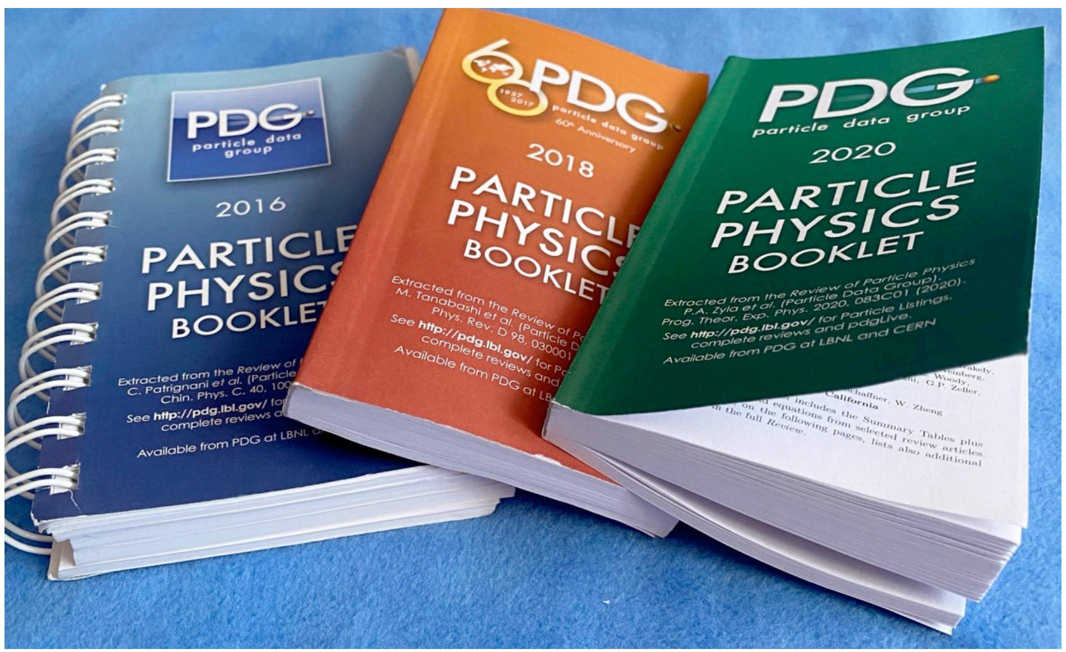


What’s new?

CHARM 2018 CHARM 2021

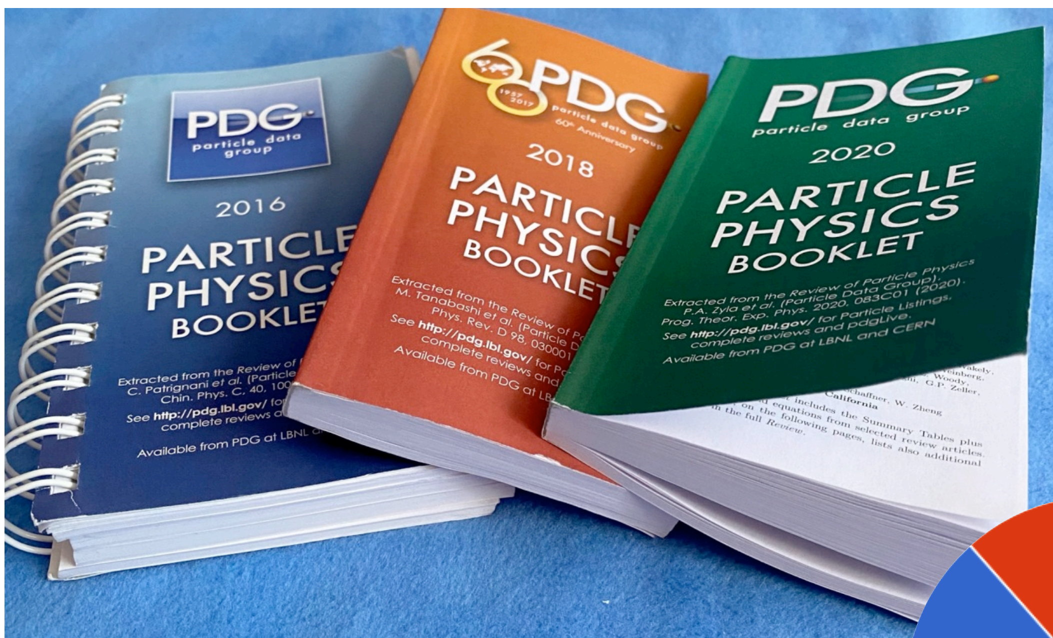


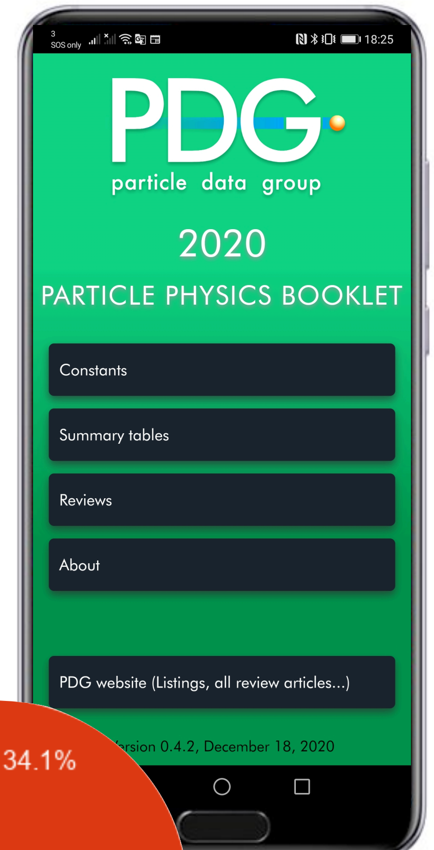
[Android App]

[Web Version]

What's new?

CHARM 2018 CHARM 2021

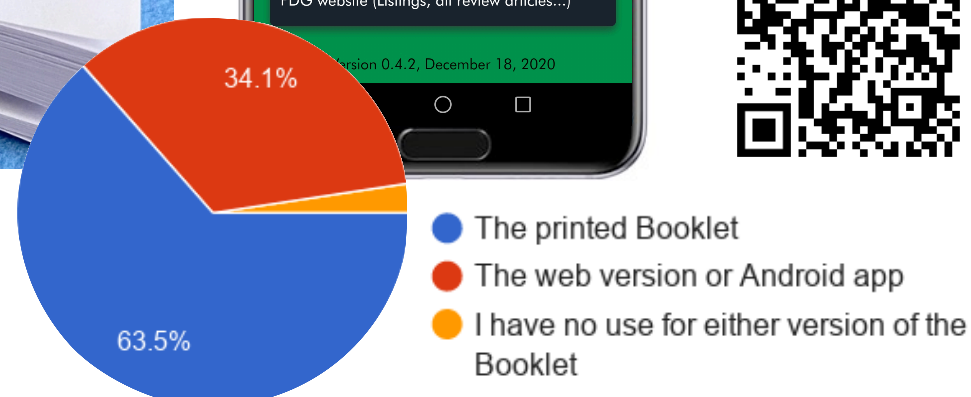




[Android App]

[Web Version]

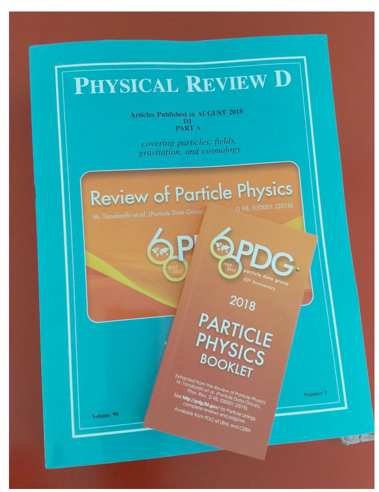
Which version of the booklet do you prefer to use primarily in the future?

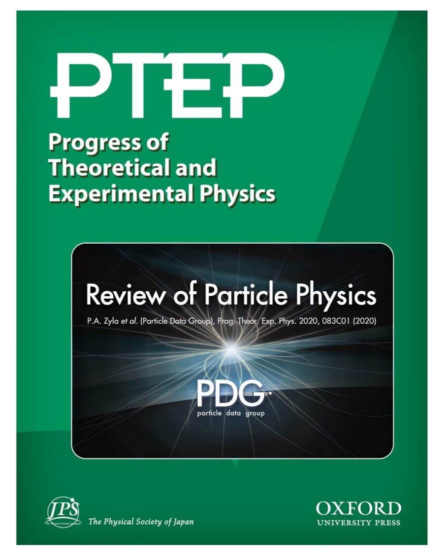


What’s new?

updated 1 June 2021

Fat book slim





The future

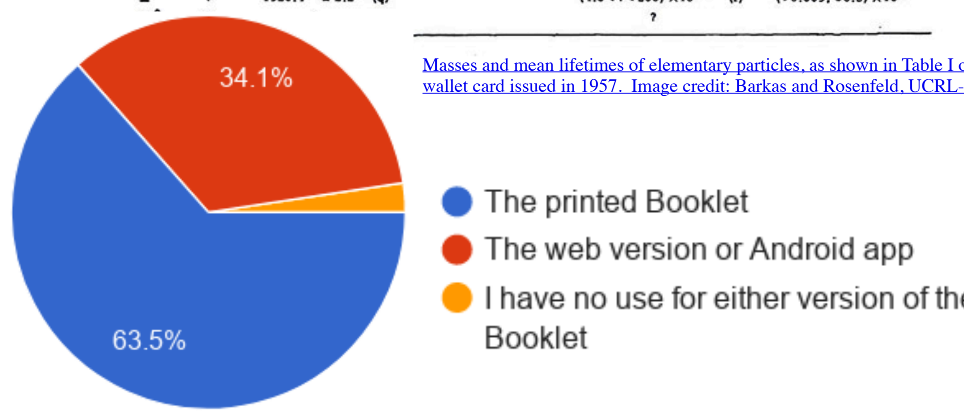
- With only 64 years of age, the PDG feels younger than ever.
- Managing the ever increasing data and presenting them in an accessible way has become increasingly difficult.
- Clearly, online/app will be increasingly important (but books still very popular).
- Currently working on making all PDG data available in machine readable form.

Barkas and Rosenfeld UCRL-8030 Table I

Masses and mean lives of elementary particles; November, 1957
(The antiparticles are assumed to have the same spins, masses, and mean lives as the particles listed)

	Particle	Spin	Mass (Errors represent standard deviation) (Mev)	Mass difference (Mev)	Mean life (sec)	Decay rate (number per second)
Photon	γ	1	0		stable	0
Leptons	ν	$\frac{1}{2}$	0		stable	0
	e^-	$\frac{1}{2}$	0.510976 (a)		stable	0
	μ^-	$\frac{1}{2}$	105.70 $\pm$0.06 (a)		(2.22 $\pm$0.02) $\times 10^{-6}$	0.45 $\times 10^{6}$
Mesons	π^+	0	139.63 $\pm$0.06 (a)	4.6 (a)	(2.56 $\pm$0.05) $\times 10^{-8}$ (a)	0.39 $\times 10^{8}$
	π^0	0	135.04 $\pm$0.16 (a)		< 4 $\times 10^{-16}$ (d)	> 2.5 $\times 10^{15}$
	K^+	0	494.0 $\pm$0.2 (g)	0.4$\pm$1.8	(1.224$\pm$0.013) $\times 10^{-8}$ (h)	0.815 $\times 10^{8}$
	K^0	0	494.4 $\pm$1.8 (i)		K_1: (0.95 $\pm$0.08) $\times 10^{-10}$ (e)	1.05 $\times 10^{10}$
					K_2: ($4<\tau<13$) $\times 10^{-8}$ (c)	($0.07<\tau<0.25$) $\times 10^{8}$
Baryons	p	$\frac{1}{2}$	938.213 $\pm$0.01 (a)		stable	0.0
	n	$\frac{1}{2}$	939.506 $\pm$0.01 (a)		(1.04 $\pm$0.13) $\times 10^{+3}$ (a)	0.96 $\times 10^{-3}$
	Λ	$\frac{1}{2}$	1115.2 $\pm$0.14 (j)		(2.77 $\pm$0.15) $\times 10^{-10}$ (k)	0.36 $\times 10^{10}$
	Σ^+	$\frac{1}{2}$	1189.4 $\pm$0.25 (l)	7.1 $\pm$ 0.4	(0.83 $^{+.06}_{-.05}$) $\times 10^{-10}$ (m)	1.21 $\times 10^{10}$
	Σ^-	$\frac{1}{2}$	1196.5 $\pm$0.5 (n)		(1.67 $\pm$0.17) $\times 10^{-10}$ (o)	0.60 $\times 10^{10}$
	Σ^0	$\frac{1}{2}$	1190.5$^{+0.9}_{-1.4}$ (p)	6.0$^{+1.4}_{-0.9}$	(<0.1) $\times 10^{-10}$ (b) theoretically ~10^{-19}	> 10 $\times 10^{10}$ theoretically ~10^{19}
	Ξ^-	?	1320.4 $\pm$ 2.2 (q)		($4.6<\tau<200$) $\times 10^{-10}$ (f)	(>0.005, <0.2) $\times 10^{10}$
					?	

Masses and mean lifetimes of elementary particles, as shown in Table I of the first wallet card issued in 1957. Image credit: Barkas and Rosenfeld, UCRL-8030.



DOE Science
@doescience

The 2,000+ page book of particle physics reference data managed by the Particle Data Group started in 1957 as a simple wallet card. Since then, it's grown to be the reference guide for particle physicists. Get to know this #SCPuReData resource: pdg.lbl.gov

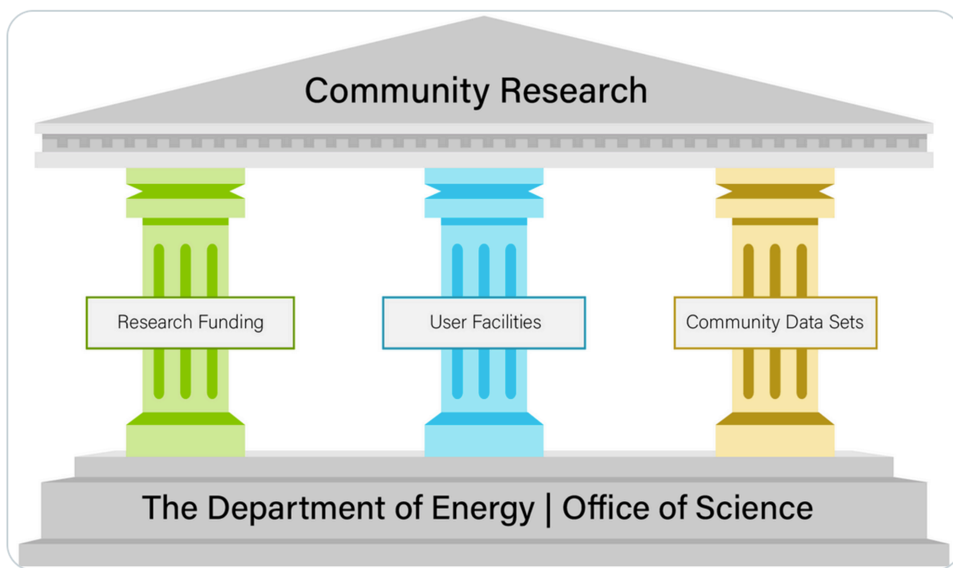
9:56 pm · 26 May 2021 · Sprout Social

Public Reusable Research (PuRe) Data Resources

PDG has been been designated by the DOE as a PuRe resource.

DOE Science
@doescience

You want data? We've got data! In fact, @Energy Office of Science has developed a new way to designate our best data sets that are the authoritative resources in their communities. Learn about our PuRe data resources. #SCPuReData energy.gov/science/articl...



4:15 pm · 13 Apr 2021 · Sprout Social

Browsing through the D^0 listings

2018

M. Tanabashi et al. (Particle Data Group), Phys. Rev. D 98, 030001 (2018)

Citation: M. Tanabashi *et al.* (Particle Data Group), Phys. Rev. D **98**, 030001 (2018)

$\boxed{D^0}$ $I(J^P) = \frac{1}{2}(0^-)$

D^0 MASS

The fit includes $D^{\pm}$, D^0, $D_s^{\pm}$, $D^{*\pm}$, D^{*0}, $D_s^{*\pm}$, $D_1(2420)^0$, $D_2^*(2460)^0$, and $D_{s1}(2536)^{\pm}$ mass and mass difference measurements.

Given the recent addition of much more precise measurements, we have omitted all those masses published up through 1990. See any Review before 2015 for those earlier results.

VALUE (MeV)	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
1864.83 ±0.05 OUR FIT					
1864.84 ±0.05 OUR AVERAGE					
1864.845±0.025±0.057	63k	[1] TOMARADZE	14		$D^0 \to K^- 2\pi^+ \pi^-$
1864.75 ±0.15 ±0.11		AAIJ	13V	LHCB	$D^0 \to K^+ 2K^- \pi^+$
1864.841±0.048±0.063	4.3k	[2] LEES	13S	BABR	e^+e^- at $\Upsilon(4S)$
1865.30 ±0.33 ±0.23	0.1k	ANASHIN	10A	KEDR	e^+e^- at $\psi(3770)$
1864.847±0.150±0.095	0.3k	CAWLFIELD	07	CLEO	$D^0 \to K_S^0 \phi$

[1] Obtained by analyzing CLEO-c data but not authored by the CLEO Collaboration. The largest source of error in the TOMARADZE 14 value is from the uncertainties in the K^- and K_S^0 masses. The systematic error given above is the addition in quadrature of $\pm 0.022 \pm 0.053$ MeV, where the second error is from those mass uncertainties.

[2] The largest source of error in the LEES 13S value is from the uncertainty of the K^+ mass. The quoted systematic error is in fact $\pm 0.043 + 3\,(m_{K^+} - 493.677)$, in MeV.

$m_{D^\pm} - m_{D^0}$

The fit includes $D^{\pm}$, D^0, $D_s^{\pm}$, $D^{*\pm}$, D^{*0}, $D_s^{*\pm}$, $D_1(2420)^0$, $D_2^*(2460)^0$, and $D_{s1}(2536)^{\pm}$ mass and mass difference measurements.

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
4.822±0.015 OUR FIT				
4.76 ±0.12 ±0.07	AAIJ	13V	LHCB	$D^+ \to K^+ K^- \pi^+$

D^0 MEAN LIFE

Measurements with an error $> 10 \times 10^{-15}$ s have been omitted from the average.

VALUE (10^{-15} s)	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
410.1± 1.5 OUR AVERAGE					
409.6± 1.1± 1.5	210k	LINK	02F	FOCS	γ nucleus, ≈ 180 GeV
407.9± 6.0± 4.3	10k	KUSHNIR...	01	SELX	$K^-\pi^+$, $K^-\pi^+\pi^+\pi^-$
413 ± 3 ± 4	35k	AITALA	99E	E791	$K^-\pi^+$
408.5± $4.1^{+3.5}_{-3.4}$	25k	BONVICINI	99	CLE2	$e^+e^- \approx \Upsilon(4S)$
413 ± 4 ± 3	16k	FRABETTI	94D	E687	$K^-\pi^+$, $K^-\pi^+\pi^+\pi^-$

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2021

P.A. Zyla et al. (Particle Data Group), Prog. Theor. Exp. Phys. 2020, 083C01 (2020) and 2021 update

Citation: P.A. Zyla *et al.* (Particle Data Group), Prog. Theor. Exp. Phys. **2020**, 083C01 (2020) and 2021 update

$\boxed{D^0}$ $I(J^P) = \frac{1}{2}(0^-)$

D^0 MASS

The fit includes $D^{\pm}$, D^0, $D_s^{\pm}$, $D^{*\pm}$, D^{*0}, $D_s^{*\pm}$, $D_1(2420)^0$, $D_2^*(2460)^0$, and $D_{s1}(2536)^{\pm}$ mass and mass difference measurements.

Given the recent addition of much more precise measurements, we have omitted all those masses published up through 1990. See any Review before 2015 for those earlier results.

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1864.75 ±0.15 ±0.11		AAIJ	13V	LHCB	$D^0 \to K^+ 2K^- \pi^+$
1864.841±0.048±0.063	4.3k	[2] LEES	13S	BABR	e^+e^- at $\Upsilon(4S)$
1865.30 ±0.33 ±0.23	0.1k	ANASHIN	10A	KEDR	e^+e^- at $\psi(3770)$
1864.847±0.150±0.095	0.3k	CAWLFIELD	07	CLEO	$D^0 \to K_S^0 \phi$

[1] Obtained by analyzing CLEO-c data but not authored by the CLEO Collaboration. The largest source of error in the TOMARADZE 14 value is from the uncertainties in the K^- and K_S^0 masses. The systematic error given above is the addition in quadrature of $\pm 0.022 \pm 0.053$ MeV, where the second error is from those mass uncertainties.

[2] The largest source of error in the LEES 13S value is from the uncertainty of the K^+ mass. The quoted systematic error is in fact $\pm 0.043 + 3\,(m_{K^+} - 493.677)$, in MeV.

$m_{D^\pm} - m_{D^0}$

The fit includes $D^{\pm}$, D^0, $D_s^{\pm}$, $D^{*\pm}$, D^{*0}, $D_s^{*\pm}$, $D_1(2420)^0$, $D_2^*(2460)^0$, and $D_{s1}(2536)^{\pm}$ mass and mass difference measurements.

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4.76 ±0.12 ±0.07	AAIJ	13V	LHCB	$D^+ \to K^+ K^- \pi^+$

D^0 MEAN LIFE

Measurements with an error $> 10 \times 10^{-15}$ s have been omitted from the average.

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409.6± 1.1± 1.5	210k	LINK	02F	FOCS	γ nucleus, ≈ 180 GeV
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413 ± 3 ± 4	35k	AITALA	99E	E791	$K^-\pi^+$
408.5± $4.1^{+3.5}_{-3.4}$	25k	BONVICINI	99	CLE2	$e^+e^- \approx \Upsilon(4S)$
413 ± 4 ± 3	16k	FRABETTI	94D	E687	$K^-\pi^+$, $K^-\pi^+\pi^+\pi^-$

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Browsing through the D^0 listings

Citation: M. Tanabashi *et al.* (Particle Data Group), Phys. Rev. D **98**, 030001 (2018)

• • • We do not use the following data for averages, fits, limits, etc. • • •

424	±11	± 7	5118	FRABETTI	91	E687	$K^-\pi^+$, $K^-\pi^+\pi^+\pi^-$
417	±18	±15	890	ALVAREZ	90	NA14	$K^-\pi^+$, $K^-\pi^+\pi^+\pi^-$
388	$^{+23}_{-21}$		641	[1] BARLAG	90C	ACCM	π^- Cu 230 GeV
480	±40	±30	776	ALBRECHT	88I	ARG	e^+e^- 10 GeV
422	± 8	±10	4212	RAAB	88	E691	Photoproduction
420	±50		90	BARLAG	87B	ACCM	K^- and π^- 200 GeV

[1] BARLAG 90C estimate systematic error to be negligible.

See the related review(s):

D^0 — $\overline{D}^0$ Mixing

$$\left|m_{D_1^0} - m_{D_2^0}\right| = x\,\Gamma$$

The D_1^0 and D_2^0 are the mass eigenstates of the D^0 meson, as described in the note on "D^0-$\overline{D}^0$ Mixing,' above. The experiments usually present $x \equiv \Delta m/\Gamma$. Then $\Delta m = x\,\Gamma = x\,\hbar/\tau$.

"OUR EVALUATION" comes from CPV allowing averages provided by the Heavy Flavor Averaging Group, see the note on "D^0-$\overline{D}^0$ Mixing."

VALUE ($10^{10}\ \hbar\ s^{-1}$)	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
$\mathbf{0.95^{+0.41}_{-0.44}}$ **OUR EVALUATION**					
0.8 ±0.7 OUR AVERAGE Error includes scale factor of 1.7. See the ideogram below.					
		[1] AAIJ	17AO	LHCB	pp at 7, 8 TeV
−2.10±1.29±0.41		[2] AAIJ	16V	LHCB	pp at 7 TeV
3.7 ±2.9 ±1.5		[3] LEES	16D	BABR	e^+e^-, 10.6 GeV
		[4] KO	14	BELL	$e^+e^- \to \Upsilon(nS)$
$1.37\pm0.46^{+0.18}_{-0.28}$		[5] PENG	14	BELL	$e^+e^- \to \Upsilon(nS)$
		[6] AALTONEN	13AE	CDF	$p\overline{p}$ at 1.96 TeV
0.39±0.56±0.35		[7] DEL-AMO-SA..	10D	BABR	e^+e^-, 10.6 GeV
• • • We do not use the following data for averages, fits, limits, etc. • • •					
		[8] AAIJ	13CE	LHCB	Repl. by AAIJ 17AO
		[9] AAIJ	13N	LHCB	Repl. by AAIJ 13CE
$6.4\ ^{+1.4}_{-1.7}\ \pm1.0$		[10] AUBERT	09AN	BABR	e^+e^- at 10.58 GeV
$-2\ ^{+7}_{-6}$		[11] LOWREY	09	CLEO	e^+e^- at $\psi(3770)$
$1.98\pm0.73^{+0.32}_{-0.41}$		[12] ZHANG	07B	BELL	Repl. by PENG 14
< 7	95	[13] ZHANG	06	BELL	e^+e^-
−11 to +22		[12] ASNER	05	CLEO	$e^+e^- \approx$ 10 GeV
< 11	90	BITENC	05	BELL	
< 30	90	CAWLFIELD	05	CLEO	

Citation: P.A. Zyla *et al.* (Particle Data Group), Prog. Theor. Exp. Phys. **2020**, 083C01 (2020) and 2021 update

• • • We do not use the following data for averages, fits, limits, etc. • • •

424	±11	± 7	5118	FRABETTI	91	E687	$K^-\pi^+$, $K^-\pi^+\pi^+\pi^-$
417	±18	±15	890	ALVAREZ	90	NA14	$K^-\pi^+$, $K^-\pi^+\pi^+\pi^-$
388	$^{+23}_{-21}$		641	[1] BARLAG	90C	ACCM	π^- Cu 230 GeV
480	±40	±30	776	ALBRECHT	88I	ARG	e^+e^- 10 GeV
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420	±50		90	BARLAG	87B	ACCM	K^- and π^- 200 GeV

[1] BARLAG 90C estimate systematic error to be negligible.

See the related review(s):

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$$\left|m_{D_1^0} - m_{D_2^0}\right| = x\,\Gamma$$

The D_1^0 and D_2^0 are the mass eigenstates of the D^0 meson, as described in the note on "D^0-$\overline{D}^0$ Mixing,' above. The experiments usually present $x \equiv \Delta m/\Gamma$. Then $\Delta m = x\,\Gamma = x\,\hbar/\tau$.

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VALUE ($10^{10}\ \hbar\ s^{-1}$)	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
$\mathbf{0.95^{+0.41}_{-0.44}}$ **OUR EVALUATION**					
0.7 ±0.4 OUR AVERAGE Error includes scale factor of 1.4. See the ideogram below.					
$0.66^{+0.41}_{-0.37}$		[1] AAIJ	19X	LHCB	$D^0 \to K_S^0\pi^+\pi^-$
		[2] AAIJ	18K	LHCB	pp at 7, 8, 13 TeV
−2.10±1.29±0.41		[3] AAIJ	16V	LHCB	pp at 7 TeV
3.7 ±2.9 ±1.5		[4] LEES	16D	BABR	e^+e^-, 10.6 GeV
		[5] KO	14	BELL	$e^+e^- \to \Upsilon(nS)$
$1.37\pm0.46^{+0.18}_{-0.28}$		[6] PENG	14	BELL	$e^+e^- \to \Upsilon(nS)$
		[7] AALTONEN	13AE	CDF	$p\overline{p}$ at 1.96 TeV
0.39±0.56±0.35		[8] DEL-AMO-SA..	10D	BABR	e^+e^-, 10.6 GeV
• • • We do not use the following data for averages, fits, limits, etc. • • •					
		[9] AAIJ	17AO	LHCB	Repl. by AAIJ 18K
		[10] AAIJ	13CE	LHCB	Repl. by AAIJ 17AO
		[11] AAIJ	13N	LHCB	Repl. by AAIJ 13CE
$6.4\ ^{+1.4}_{-1.7}\ \pm1.0$		[12] AUBERT	09AN	BABR	e^+e^- at 10.58 GeV
$-2\ ^{+7}_{-6}$		[13] LOWREY	09	CLEO	e^+e^- at $\psi(3770)$
$1.98\pm0.73^{+0.32}_{-0.41}$		[14] ZHANG	07B	BELL	Repl. by PENG 14
< 7	95	[15] ZHANG	06	BELL	e^+e^-
−11 to +22		[14] ASNER	05	CLEO	$e^+e^- \approx$ 10 GeV
< 11	90	BITENC	05	BELL	

Browsing through the D^0 listings

Citation: M. Tanabashi *et al.* (Particle Data Group), Phys. Rev. D **98**, 030001 (2018)

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388			90C	ACCM	π^- Cu 230 GeV
				ARG	e^+e^- 10 GeV
					Photoproduction
					K^- and π^- 200 GeV

D^0 — $\overline{D}^0$ Mixing

described

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"D^0-$\overline{D}^0$ Mixing."

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< 11	90	BITENC	05	BELL	
< 30	90	CAWLFIELD	05	CLEO	

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Citation: P.A. Zyla *et al.* (Particle Data Group), Prog. Theor. Exp. Phys. **2020**, 083C01 (2020) and 2021 update

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VALUE (10^{10} $\hbar$ s^{-1})	CL%	DOCUMENT ID		TECN	COMMENT
$0.95^{+0.41}_{-0.44}$ OUR EVALUATION					
0.7 ±0.4 OUR AVERAGE Error includes scale factor of 1.4. See the ideogram below.					
$0.66^{+0.41}_{-0.37}$		[1] AAIJ	19X	LHCB	$D^0 \to K_S^0\pi^+\pi^-$
		[2] AAIJ	18K	LHCB	pp at 7, 8, 13 TeV
$-2.10\pm1.29\pm0.41$		[3] AAIJ	16V	LHCB	pp at 7 TeV
3.7 ±2.9 ±1.5		[4] LEES	16D	BABR	e^+e^-, 10.6 GeV
		[5] KO	14	BELL	$e^+e^- \to \Upsilon(nS)$
$1.37\pm0.46^{+0.18}_{-0.28}$		[6] PENG	14	BELL	$e^+e^- \to \Upsilon(nS)$
		[7] AALTONEN	13AE	CDF	$p\overline{p}$ at 1.96 TeV
$0.39\pm0.56\pm0.35$		[8] DEL-AMO-SA...	10D	BABR	e^+e^-, 10.6 GeV
• • • We do not use the following data for averages, fits, limits, etc. • • •					
		[9] AAIJ	17AO	LHCB	Repl. by AAIJ 18K
		[10] AAIJ	13CE	LHCB	Repl. by AAIJ 17AO
		[11] AAIJ	13N	LHCB	Repl. by AAIJ 13CE
$6.4\ ^{+1.4}_{-1.7}\ \pm1.0$		[12] AUBERT	09AN	BABR	e^+e^- at 10.58 GeV
$-2\ ^{+7}_{-6}$		[13] LOWREY	09	CLEO	e^+e^- at $\psi(3770)$
$1.98\pm0.73^{+0.32}_{-0.41}$		[14] ZHANG	07B	BELL	Repl. by PENG 14
< 7	95	[15] ZHANG	06	BELL	e^+e^-
−11 to +22		[14] ASNER	05	CLEO	$e^+e^- \approx$ 10 GeV
< 11	90	BITENC	05	BELL	

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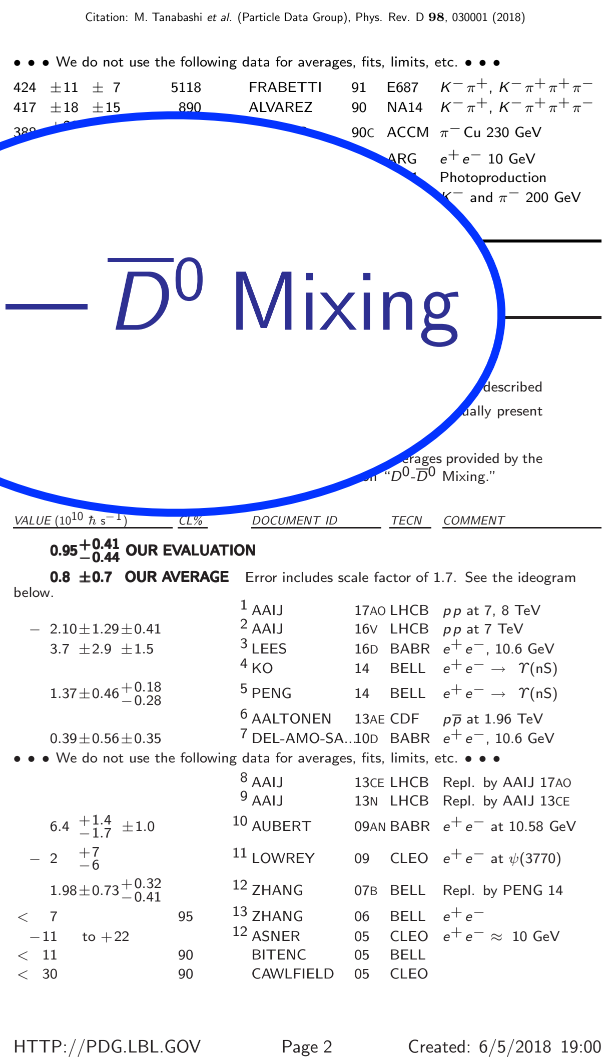
Browsing through the D^0 listings



Citation: M. Tanabashi *et al.* (Particle Data Group), Phys. Rev. D **98**, 030001 (2018)

• • • We do not use the following data for averages, fits, limits, etc. • • •

424 ±11 ± 7	5118	FRABETTI 91	E687	$K^-\pi^+$, $K^-\pi^+\pi^+\pi^-$
417 ±18 ±15	890	ALVAREZ 90	NA14	$K^-\pi^+$, $K^-\pi^+\pi^+\pi^-$
388		90C	ACCM	π^- Cu 230 GeV
			ARG	e^+e^- 10 GeV
				Photoproduction
				K^- and π^- 200 GeV

$D^0 — \overline{D}{}^0$ Mixing

described

ually present

erages provided by the

"D^0-$\overline{D}{}^0$ Mixing."

VALUE (10^{10} $\hbar$ s^{-1})	CL%	DOCUMENT ID	TECN	COMMENT
$0.95^{+0.41}_{-0.44}$ **OUR EVALUATION**				
0.8 ±0.7 OUR AVERAGE Error includes scale factor of 1.7. See the ideogram below.				
		[1] AAIJ 17AO	LHCB	pp at 7, 8 TeV
$-2.10\pm1.29\pm0.41$		[2] AAIJ 16V	LHCB	pp at 7 TeV
$3.7\ \pm2.9\ \pm1.5$		[3] LEES 16D	BABR	e^+e^-, 10.6 GeV
		[4] KO 14	BELL	$e^+e^- \to \Upsilon(nS)$
$1.37\pm0.46^{+0.18}_{-0.28}$		[5] PENG 14	BELL	$e^+e^- \to \Upsilon(nS)$
		[6] AALTONEN 13AE	CDF	$p\overline{p}$ at 1.96 TeV
$0.39\pm0.56\pm0.35$		[7] DEL-AMO-SA..10D	BABR	e^+e^-, 10.6 GeV
• • • We do not use the following data for averages, fits, limits, etc. • • •				
		[8] AAIJ 13CE	LHCB	Repl. by AAIJ 17AO
		[9] AAIJ 13N	LHCB	Repl. by AAIJ 13CE
$6.4\ ^{+1.4}_{-1.7}\ \pm1.0$		[10] AUBERT 09AN	BABR	e^+e^- at 10.58 GeV
$-2\ ^{+7}_{-6}$		[11] LOWREY 09	CLEO	e^+e^- at $\psi(3770)$
$1.98\pm0.73^{+0.32}_{-0.41}$		[12] ZHANG 07B	BELL	Repl. by PENG 14
$<\ 7$	95	[13] ZHANG 06	BELL	e^+e^-
-11 to $+22$		[12] ASNER 05	CLEO	$e^+e^- \approx$ 10 GeV
$<\ 11$	90	BITENC 05	BELL	
$<\ 30$	90	CAWLFIELD 05	CLEO	

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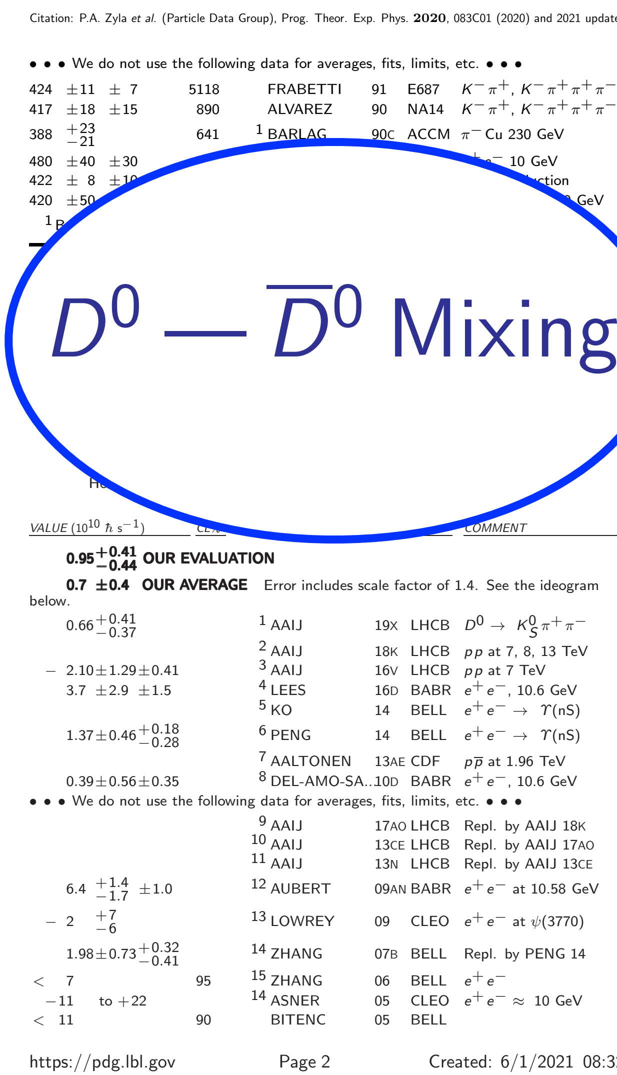

Citation: P.A. Zyla *et al.* (Particle Data Group), Prog. Theor. Exp. Phys. **2020**, 083C01 (2020) and 2021 update

• • • We do not use the following data for averages, fits, limits, etc. • • •

424 ±11 ± 7	5118	FRABETTI 91	E687	$K^-\pi^+$, $K^-\pi^+\pi^+\pi^-$
417 ±18 ±15	890	ALVAREZ 90	NA14	$K^-\pi^+$, $K^-\pi^+\pi^+\pi^-$
$388\ ^{+23}_{-21}$	641	[1] BARLAG 90C	ACCM	π^- Cu 230 GeV
480 ±40 ±30				10 GeV
422 ± 8				ction
420 ±50				GeV

$D^0 — \overline{D}{}^0$ Mixing

VALUE (10^{10} $\hbar$ s^{-1})	CL%	DOCUMENT ID	TECN	COMMENT
$0.95^{+0.41}_{-0.44}$ **OUR EVALUATION**				
0.7 ±0.4 OUR AVERAGE Error includes scale factor of 1.4. See the ideogram below.				
$0.66^{+0.41}_{-0.37}$		[1] AAIJ 19X	LHCB	$D^0 \to K^0_S\pi^+\pi^-$
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$-2.10\pm1.29\pm0.41$		[3] AAIJ 16V	LHCB	pp at 7 TeV
$3.7\ \pm2.9\ \pm1.5$		[4] LEES 16D	BABR	e^+e^-, 10.6 GeV
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$0.39\pm0.56\pm0.35$		[8] DEL-AMO-SA..10D	BABR	e^+e^-, 10.6 GeV
• • • We do not use the following data for averages, fits, limits, etc. • • •				
		[9] AAIJ 17AO	LHCB	Repl. by AAIJ 18K
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$-2\ ^{+7}_{-6}$		[13] LOWREY 09	CLEO	e^+e^- at $\psi(3770)$
$1.98\pm0.73^{+0.32}_{-0.41}$		[14] ZHANG 07B	BELL	Repl. by PENG 14
$<\ 7$	95	[15] ZHANG 06	BELL	e^+e^-
-11 to $+22$		[14] ASNER 05	CLEO	$e^+e^- \approx$ 10 GeV
$<\ 11$	90	BITENC 05	BELL	

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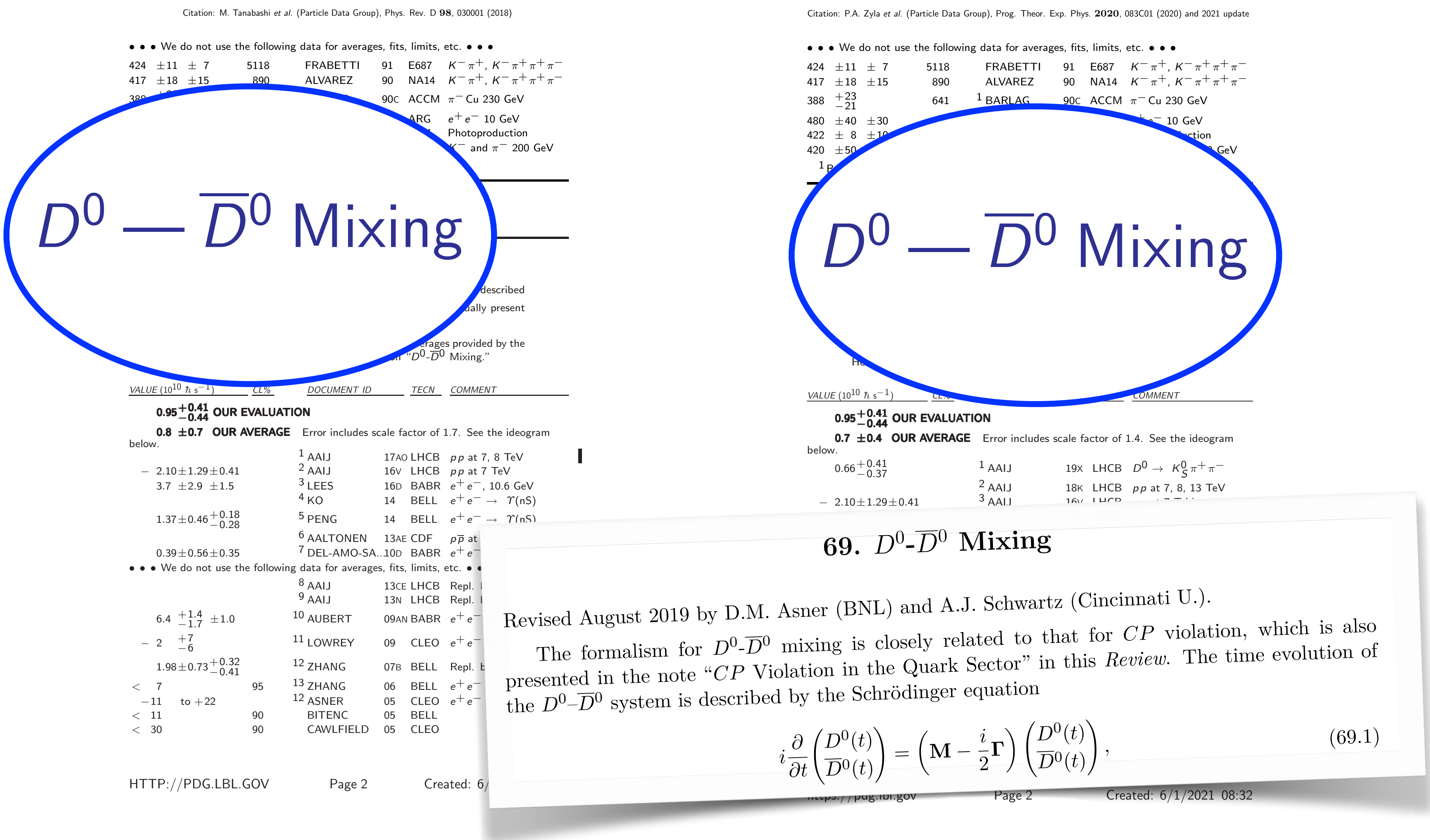
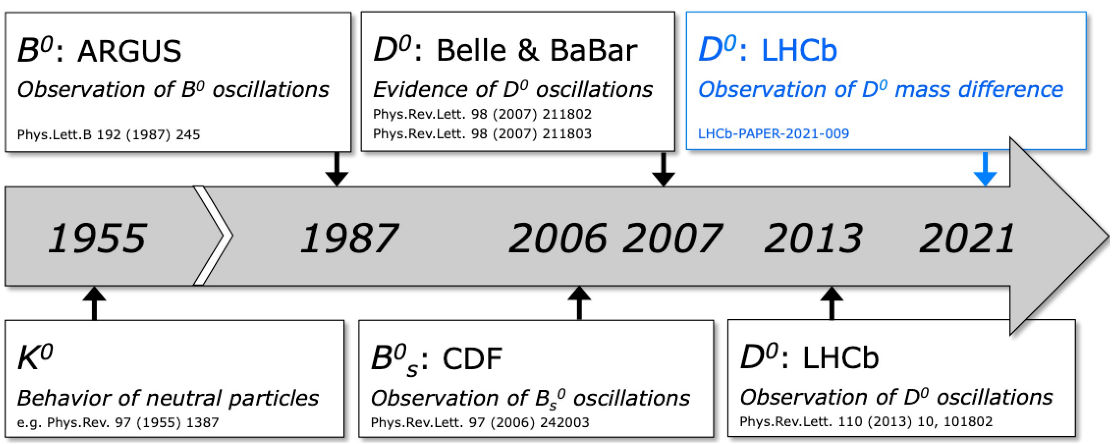
Browsing through the D^0 listings

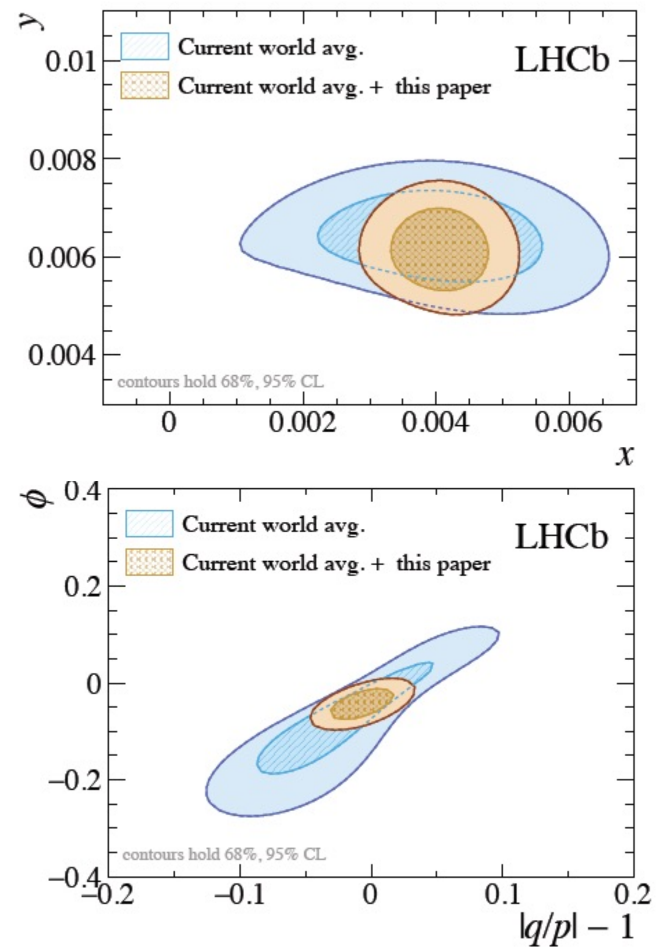


D mixing

- Amazing progress reported by Angelo this morning!



LHCB-PAPER-2019-001



D mixing

- PDG takes charm mixing results ($x, y, \phi, |q/p|$) from HFLAV, who kindly re-calculate it for us according to PDG rules (only published results, no preprints).

HFLAV

Y. Amhis et al. (Heavy Flavor Averaging Group) (2018), [arXiv:1909.12524], updated results and plots available at https://hflav.web.cern.ch/

- So, while an exciting topic with impressive progress, you have learnt all about this in Jolanta's talk.

- More about HFLAV and its connection to the PDG can be found in the PDG review on HFLAV:

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Heavy Flavor Averaging Group

Revised August 2019 by U. Egede (Monash University) and A. Soffer (Tel Aviv University)

The Heavy Flavor Averaging Group (HFLAV)* is an international collaboration of

… a gem around 100 pages further down:

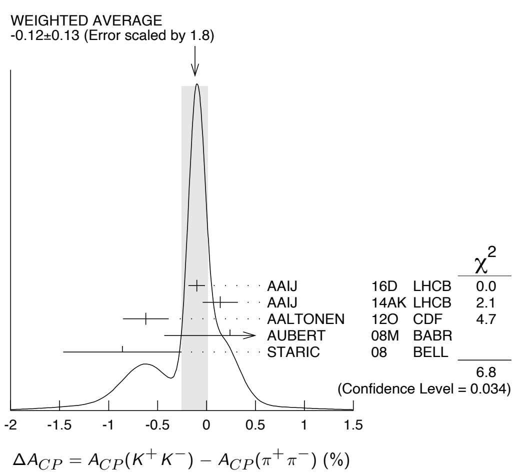
2018 $\Delta A_{CP} = A_{CP}(K^+K^-) - A_{CP}(\pi^+\pi^-)$ 2021

D^0 *CP*-VIOLATING ASYMMETRY DIFFERENCES

$\Delta A_{CP} = A_{CP}(K^+K^-) - A_{CP}(\pi^+\pi^-)$

CP violation in these modes can come from the decay amplitudes (direct) and/or from mixing or interference of mixing and decay (indirect). The difference ΔA_{CP} is primarily sensitive to the direct component, and only retains a second-order dependence on the indirect component for measurements where the mean decay time of the K^+K^- and $\pi^+\pi^-$ samples are not identical. The results below are averaged assuming the indirect component can be neglected.

VALUE (%)	EVTS	DOCUMENT ID		TECN	COMMENT
−0.12±0.13 OUR AVERAGE	Error includes scale factor of 1.8. See the ideogram below.				
−0.10±0.08±0.03	6.5M,2.2M	AAIJ	16D	LHCB	Time-integrated
0.14±0.16±0.08	2.2M,0.8M	AAIJ	14AK	LHCB	Time-integrated
−0.62±0.21±0.10		AALTONEN	12O	CDF	Time-integrated
0.24±0.62±0.26		[1] AUBERT	08M	BABR	Time-integrated
−0.86±0.60±0.07	120k	STARIC	08	BELL	Time-integrated
• • • We do not use the following data for averages, fits, limits, etc. • • •					
0.49±0.30±0.14	0.56M,0.22M	AAIJ	13AD	LHCB	See AAIJ 14AK
−0.82±0.21±0.11	1.4M,0.4M	AAIJ	12G	LHCB	See AAIJ 16D
−0.46±0.31±0.12		AALTONEN	12B	CDF	See AALTONEN 12O



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D^0 *CP*-VIOLATING ASYMMETRY DIFFERENCES

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VALUE (%)	EVTS	DOCUMENT ID		TECN	COMMENT
−0.154±0.029	53M,17M	AAIJ	19D	LHCB	Time-integrated
• • • We do not use the following data for averages, fits, limits, etc. • • •					
−0.10 ±0.08 ±0.03	6.5M,2.2M	AAIJ	16D	LHCB	See AAIJ 19D
0.14 ±0.16 ±0.08	2.2M,0.8M	AAIJ	14AK	LHCB	See AAIJ 19D
0.49 ±0.30 ±0.14	0.56M,0.22M	AAIJ	13AD	LHCB	See AAIJ 14AK
−0.82 ±0.21 ±0.11	1.4M,0.4M	AAIJ	12G	LHCB	See AAIJ 16D
−0.46 ±0.31 ±0.12		AALTONEN	12B	CDF	See AALTONEN 12O
−0.62 ±0.21 ±0.10		AALTONEN	12O	CDF	Time-integrated
0.24 ±0.62 ±0.26		[1] AUBERT	08M	BABR	Time-integrated
−0.86 ±0.60 ±0.07	120k	STARIC	08	BELL	Time-integrated

[1] Calculated from the AUBERT 08M values of $A_{CP}(K^+K^-)$ and $A_{CP}(\pi^+\pi^-)$. The systematic error here combines the systematic errors in quadrature, and therefore somewhat over-estimates it.

D^0 TESTS OF LOCAL *CP*-VIOLATION (*CPV*)

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Most of these searches divide phase space (Dalitz plot for 3-body decays, five-dimensional equivalent for 4-body decays) into bins, and perform a χ^2 test comparing normalised yields N_i, $\overline{N}_i$ in *CP*-conjugate bin pairs i: $\chi^2 = \Sigma_i (N_i - \alpha \overline{N}_i)/\sigma(N_i - \alpha \overline{N}_i)$. The factor $\alpha = (\Sigma_i N_i)/(\Sigma_i \overline{N}_i)$ removes the dependence on phase-space-integrated rate asymmetries. The result is used to obtain the probability (p-value) to obtain the measured χ^2 or larger under the assumption of CP conservation [AUBERT 08AO, BEDIAGA 09]. Alternative methods obtain p-values from other test variables based on unbinned analyses [WILLIAMS 11, AAIJ 14C]. Results can be combined using Fisher's method [MOSTELLER 48].

Local *CPV* in $D^0, \overline{D}^0 \to \pi^+\pi^-\pi^0$

p-value (%)	EVTS	DOCUMENT ID		TECN	COMMENT
4.9 OUR EVALUATION					
2.6	566k	[1] AAIJ	15A	LHCB	unbinned method
32.8	82k	AUBERT	08AO	BABR	χ^2

[1] Unusually, AAIJ 15A assigns an uncertainty on the p value of ±0.5%. This results from limited test statistics.

Local *CPV* in $D^0, \overline{D}^0 \to \pi^+\pi^-\pi^+\pi^-$

p-value (%)	EVTS	DOCUMENT ID		TECN	COMMENT
0.6±0.2	1.0M	[1] AAIJ	17AE	LHCB	unbinned, *P*-odd

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… a gem around 100 pages further down:

2018 $\Delta A_{CP} = A_{CP}(K^+K^-) - A_{CP}(\pi^+\pi^-)$ 2021

D^0 *CP*-VIOLATING ASYMMETRY DIFFERENCES

$\Delta A_{CP} = A_{CP}(K^+K^-) - A_{CP}(\pi^+\pi^-)$

CP violation in these modes can come from the decay amplitudes (direct) and/or from mixing or interference of mixing and decay (indirect). The difference ΔA_{CP} is primarily sensitive … second-order dependence on … the K^+K^- … the

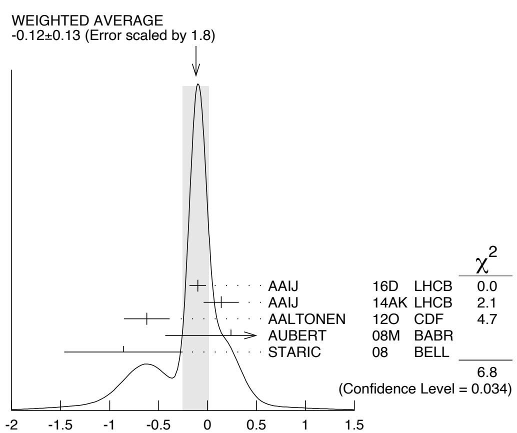
VALUE (%) … *EV*

−0.12±0.13 OUR AVERAGE

0.24±0.62…				Time-integrated
−0.86±0.60±0.07	120k	STARIC	08 BELL	Time-integrated

• • • We do not use the following data for averages, fits, limits, etc. • • •

0.49±0.30±0.14	0.56M,0.22M	AAIJ	13AD LHCB	See AAIJ 14AK
−0.82±0.21±0.11	1.4M,0.4M	AAIJ	12G LHCB	See AAIJ 16D
−0.46±0.31±0.12		AALTONEN	12B CDF	See AALTONEN 12O



$\Delta A_{CP} = A_{CP}(K^+K^-) - A_{CP}(\pi^+\pi^-)$ (%)

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D^0 *CP*-VIOLATING ASYMMETRY DIFFERENCES

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VALUE (%)	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
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• • • We do not use the following data for averages, fits, limits, etc. • • •

−0.10 ±0.08 ±0.03	6.5M,2.2M	AAIJ	16D	LHCB	See AAIJ 19D
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0.49 ±0.30 ±0.14	0.56M,0.22M	AAIJ	13AD	LHCB	See AAIJ 14AK
−0.82 ±0.21 ±0.11	1.4M,0.4M	AAIJ	12G	LHCB	See AAIJ 16D
−0.46 ±0.31 ±0.12		AALTONEN	12B	CDF	See AALTONEN 12O
−0.62 ±0.21 ±0.10		AALTONEN	12O	CDF	Time-integrated
0.24 ±0.62 ±0.26		[1] AUBERT	08M	BABR	Time-integrated
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Local *CPV* in $D^0, \overline{D}^0 \to \pi^+\pi^-\pi^0$

p-value (%)	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
4.9 OUR EVALUATION					
2.6	566k	[1] AAIJ	15A	LHCB	unbinned method
32.8	82k	AUBERT	08AO	BABR	χ^2

[1] Unusually, AAIJ 15A assigns an uncertainty on the p value of ±0.5%. This results from limited test statistics.

Local *CPV* in $D^0, \overline{D}^0 \to \pi^+\pi^-\pi^+\pi^-$

p-value (%)	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
0.6±0.2	1.0M	[1] AAIJ	17AE	LHCB	unbinned, *P*-odd

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… a gem around 100 pages further down:

2018 $$\Delta A_{CP} = A_{CP}(K^+K^-) - A_{CP}(\pi^+\pi^-)$$ 2021

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VALUE (%)	*EVT*				
-0.12 ± 0.13 OUR AVERAGE					
…					…rated
0.24 ± 0.02…					Time-integrated
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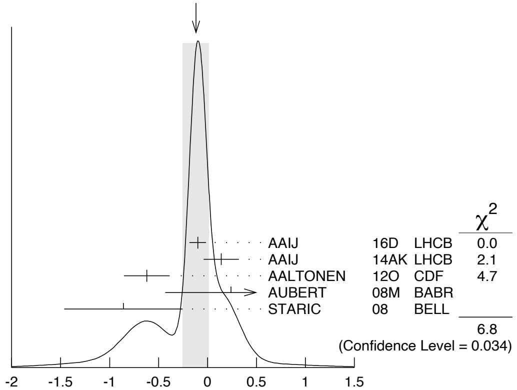
$-0.46 \pm 0.31 \pm 0.12$		AALTONEN	12B	CDF	See AALTONEN 12O



$\Delta A_{CP} = A_{CP}(K^+K^-) - A_{CP}(\pi^+\pi^-)$ (%)

HTTP://PDG.LBL.GOV Page 102 Created: 6/5/2018 19:00

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VALUE (%)							
-0.154 ± 0.029							
0.1…							
0.49	$\pm 0.$…						
-0.82	± 0.21	± 0.11					
-0.46	± 0.31	± 0.12					See AALTONEN 12O
-0.62	± 0.21	± 0.10		AALTONEN	12O	CDF	Time-integrated
0.24	± 0.62	± 0.26		[1] AUBERT	08M	BABR	Time-integrated
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Local *CPV* in $D^0, \overline{D}^0 \rightarrow \pi^+\pi^-\pi^0$

p-value (%)	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
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p-value (%)	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
0.6±0.2	1.0M	[1] AAIJ	17AE	LHCB	unbinned, *P*-odd

https://pdg.lbl.gov Page 105 Created: 6/1/2021 08:32

… a gem around 100 pages further down:

2018 $\Delta A_{CP} = A_{CP}(K^+K^-) - A_{CP}(\pi^+\pi^-)$ 2021

D^0 *CP*-VIOLATING ASYMMETRY DIFFERENCES

$\Delta A_{CP} = A_{CP}(K^+K^-) - A_{CP}(\pi^+\pi^-)$

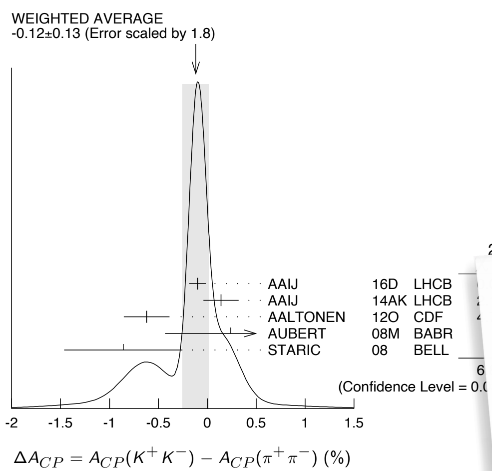
CP violation in these modes can come from the decay amplitudes (direct) and/or from mixing or interference of mixing and decay (indirect). The difference ΔA_{CP} is primarily sensitive … second-order dependence on … the K^+K^- … the

VALUE (%)	*EVT*
−0.12±0.13 OUR AVERAGE	

0.24±0.6… … Time-integrated
−0.86±0.60±0.07 120k STARIC 08 BELL Time-integrated

• • • We do not use the following data for averages, fits, limits, etc. • • •

0.49±0.30±0.14	0.56M,0.22M	AAIJ	13AD	LHCB	See AAIJ 14AK
−0.82±0.21±0.11	1.4M,0.4M	AAIJ	12G	LHCB	See AAIJ 16D
−0.46±0.31±0.12		AALTONEN	12B	CDF	See AALTONEN 12O



$\Delta A_{CP} = A_{CP}(K^+K^-) - A_{CP}(\pi^+\pi^-)$ (%)

HTTP://PDG.LBL.GOV Page 102 Created: 6/5/2018 19:00

D^0 *CP*-VIOLATING ASYMMETRY DIFFERENCES

$\Delta A_{CP} = A_{CP}(K^+K^-) - A_{CP}(\pi^+\pi^-)$

CP violation in these modes can come from the decay amplitudes (direct) and/or from mixing or interference of mixing and decay (indirect). The difference ΔA_{CP} is primarily sensitive to the direct … dependence on the indirect … and …

VALUE (%)
−0.154±0.029

0.49 ±0.…
−0.82 ±0.21 ±0.1…
−0.46 ±0.31 ±0.12 … See AALTONEN 12O
−0.62 ±0.21 ±0.10 AALTONEN 12O CDF Time-integrated
0.24 ±0.62 ±0.26 [1] AUBERT 08M BABR Time-integrated
−0.86 ±0.60 ±0.07 120k STARIC 08 BELL Time-integrated

[1] Calculated from the AUBERT 08M values of $A_{CP}(K^+K^-)$ and $A_{CP}(\pi^+\pi^-)$. The systematic error here combines the systematic errors in quadrature, and therefore somewhat over-estimates it.

D^0 TESTS OF LOCAL *CP*-VIOLATION (*CPV*)

We list model-independent searches for local *CP* violation in phase-space distributions of multi-body decays.

Most of these searches divide phase space (Dalitz plot for 3-body decays, five-dimensional equivalent for 4-body decays) into bins, and perform a χ^2 test comparing normalised yields N_i, $\overline{N}_i$ in *CP*-conjugate bin pairs i: $\chi^2 = \Sigma_i (N_i - \alpha\,\overline{N}_i)/\sigma(N_i - \alpha\,\overline{N}_i)$. The factor $\alpha = (\Sigma_i N_i)/(\Sigma_i \overline{N}_i)$ removes the dependence on phase-space-integrated rate asymmetries. The result is used to obtain the probability (p-value) to obtain the measured χ^2 or larg… under the assumption of CP conservati… Alternati…

…	*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
0.6±0.2	1.0M	[1] AAIJ 17AE	LHCB	unbinned, *P*-odd

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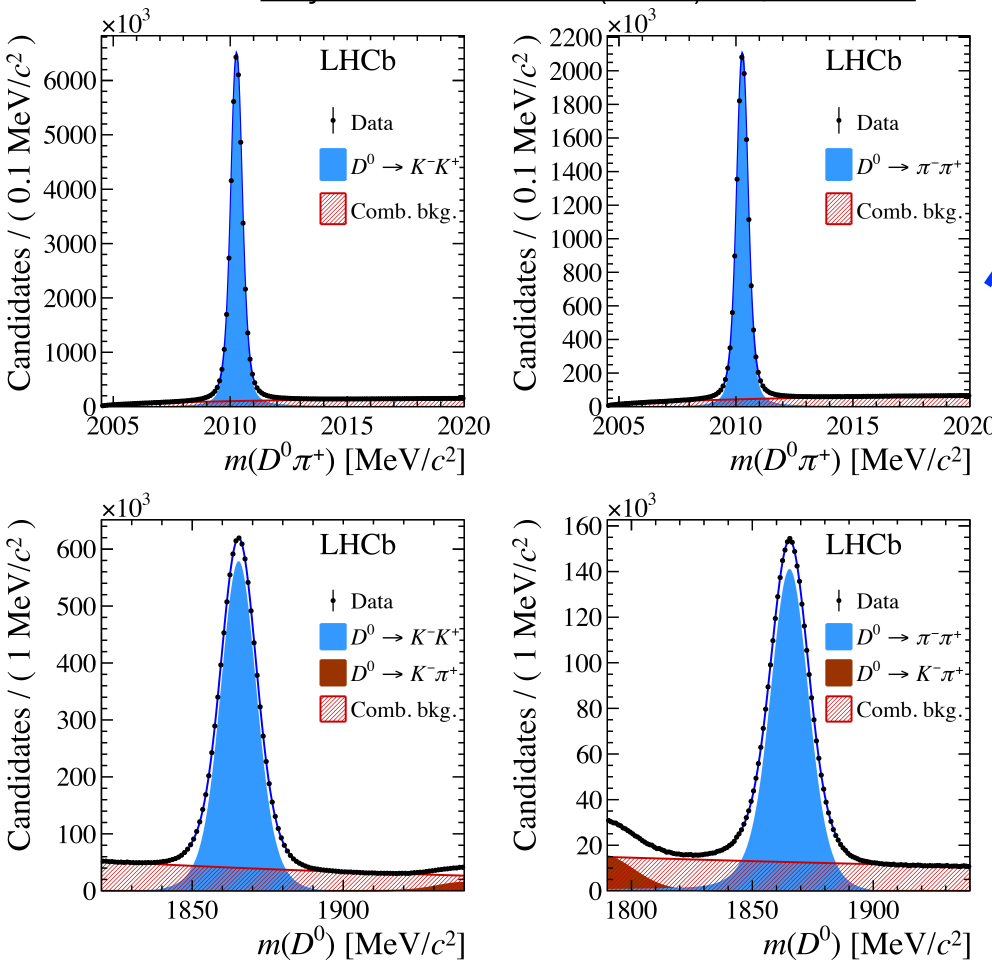
2

13. *CP* Violation in the Quark Sector

Revised August 2019 by T. Gershon (Warwick U.) and Y. Nir (Weizmann Inst.).

First observation of CP violation in charm

LHCb: Phys.Rev.Lett. 122 (2019) 21, 211803



VALUE (%)			*EVTS*
-0.154 ± 0.029			53M,17M
• • • We do not use the following d			
-0.10	± 0.08	± 0.03	6.5M,2.2M
0.14	± 0.16	± 0.08	2.2M,0.8M
0.49	± 0.30	± 0.14	0.56M,0.22M
-0.82	± 0.21	± 0.11	1.4M,0.4M
-0.46	± 0.31	± 0.12	
-0.62	± 0.21	± 0.10	
0.24	± 0.62	± 0.26	
-0.86	± 0.60	± 0.07	120k

Searches for CPV by comparing Dalitz plot shapes (binned or unbinned)

- Compare yields in CP-conjugate bins

$$S_{CP} = \frac{N_i - \alpha \overline{N}_i}{\sigma(N_i - \alpha \overline{N}_i)}$$

$$\alpha = \frac{N_{\text{total}}}{\bar{N}_{\text{total}}}$$

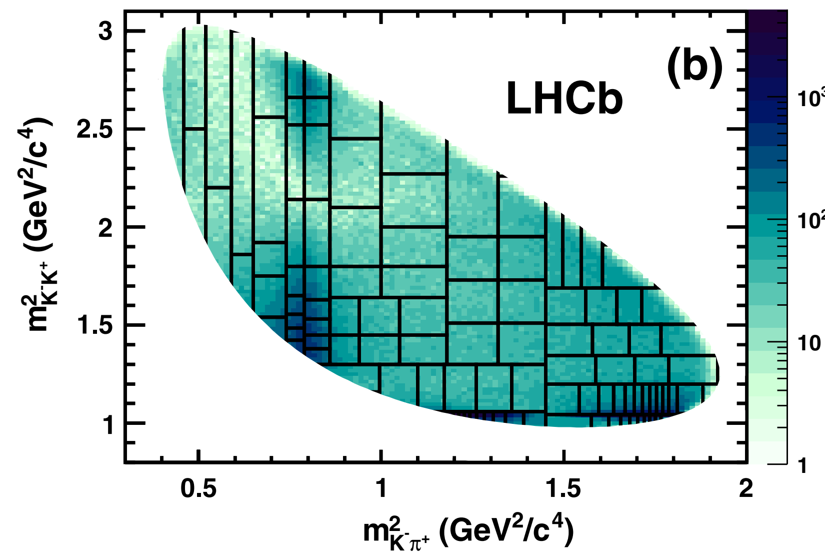
- Calculate p-value for no-CPV hypothesis based on

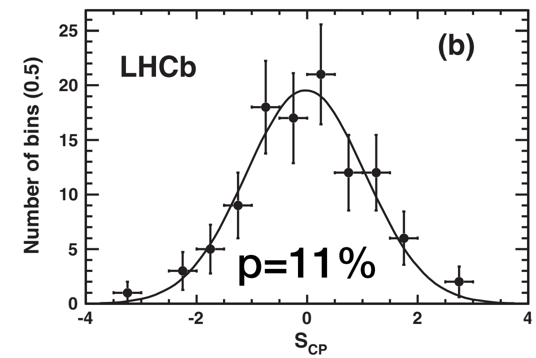
$$\chi^2 = \sum_i (S^i_{CP})^2$$

- Model independent. Many production and detection effects cancel.

Introduced by BaBar: PRD78, 051102 (2008). Developed further in PRD 80, 096006 (2009), PRD86, 036005 (2012)

330k $D^+ \to K^- K^+ \pi^+$ in 35/pb





LHCb PhysRevD.84.112008

Searches for CPV by comparing Dalitz plot shapes (binned or unbinned)

There are many others, e.g.

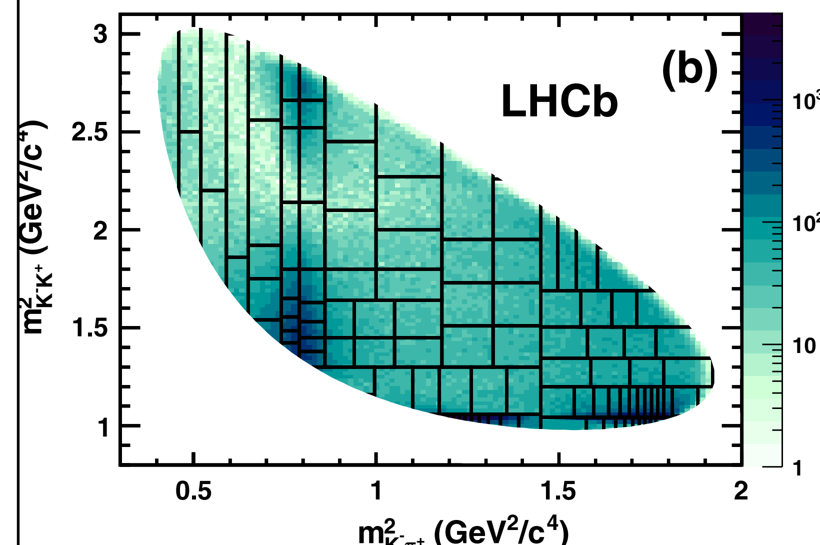
LHCb D->KKπ PRD 84.112008 (2011)
LHCb D->3π PLB 728 (2014) 585-595
CDF D->K_Sππ PRD 86, 032007 (2012)
LHCb D->ϕπ, D->K_Sπ JHEP 1306 (2013) 112
BaBar D->KKπ: PRD 87 (2013) 052010 (check)
LHCb D°->πππ° PLB 740, 158 (2015).

Generalises to 4-body decays (with 5-dimensional bins)
LHCb D->KKππ, D->4π PLB 726 (2013) 623-633

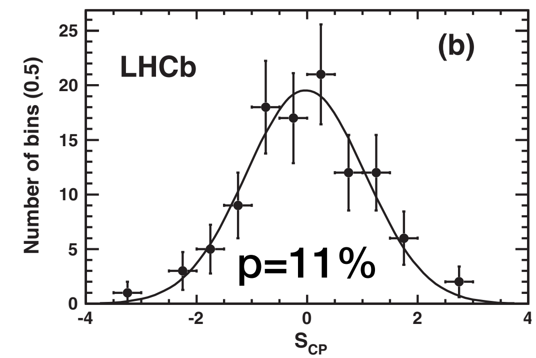
… or without bins altogether…
LHCb D->4π PLB769 (2017) 345-356

rther

330k $D^+ \to K^-K^+\pi^+$ in 35/pb



LHCb PhysRevD.84.112008



Combining local CPV results

Local *CPV* in $D^{\pm} \to K^{+} K^{-} \pi^{\pm}$

p-value (%)	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
31 OUR EVALUATION					
72	224k	LEES	13F	BABR	χ^2
12.7	370k	[1] AAIJ	11G	LHCB	χ^2

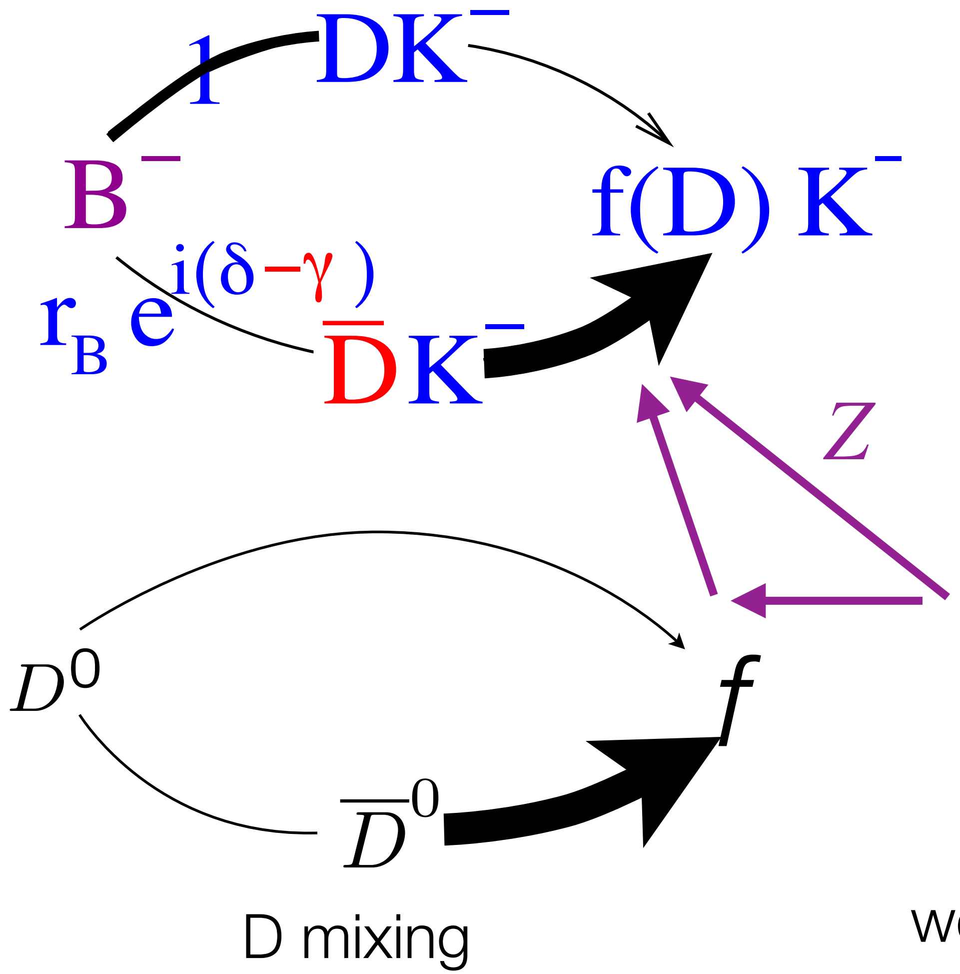
Local *CPV* in $D^0, \overline{D}^0 \to \pi^{+} \pi^{-} \pi^{0}$

p-value (%)	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
4.9 OUR EVALUATION					
2.6	566k	[1] AAIJ	15A	LHCB	unbinned method
32.8	82k	AUBERT	08AO	BABR	χ^2

Fisher's method allows the combination of p-values - it translates p-values to χ^2, adds them, then calculates a new p-value).

(Many thanks go to Mike Williams for pointing us to this method.)

Charm input to CPV in B



All three processes sensitive to the same charm interference parameters (one complex number, Z, per phase-space region)

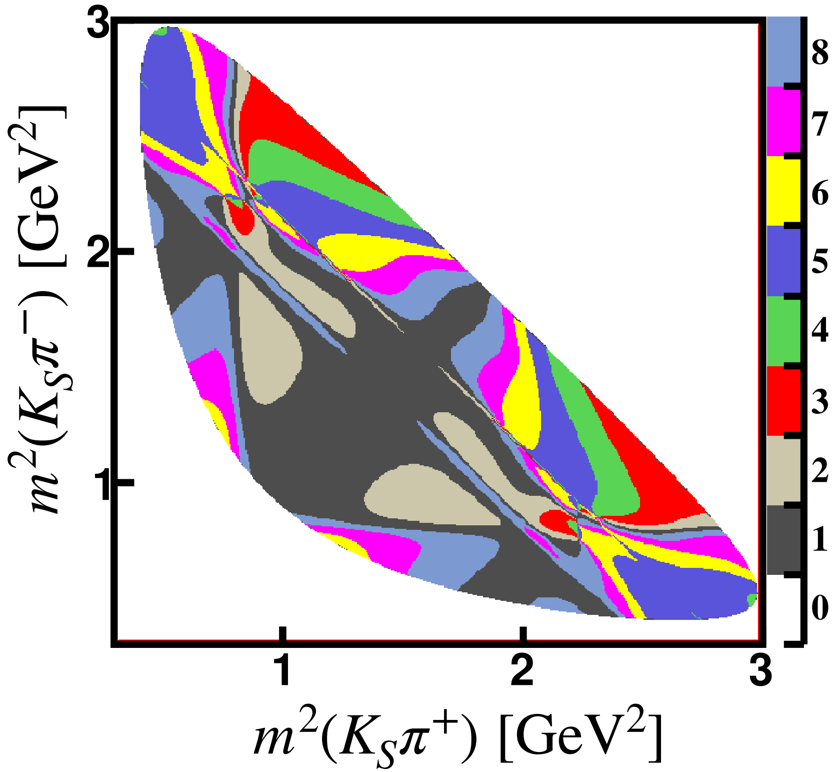
$$\frac{1}{\sqrt{2}}\left(|D^0\rangle + |\overline{D}^0\rangle\right) \to |f\rangle$$

well-defined $D^0 - \overline{D}^0$ superpositions, accessible at CLEO-c, BES III

Biggest change for charm inputs to CPV in B since 2018: BES III

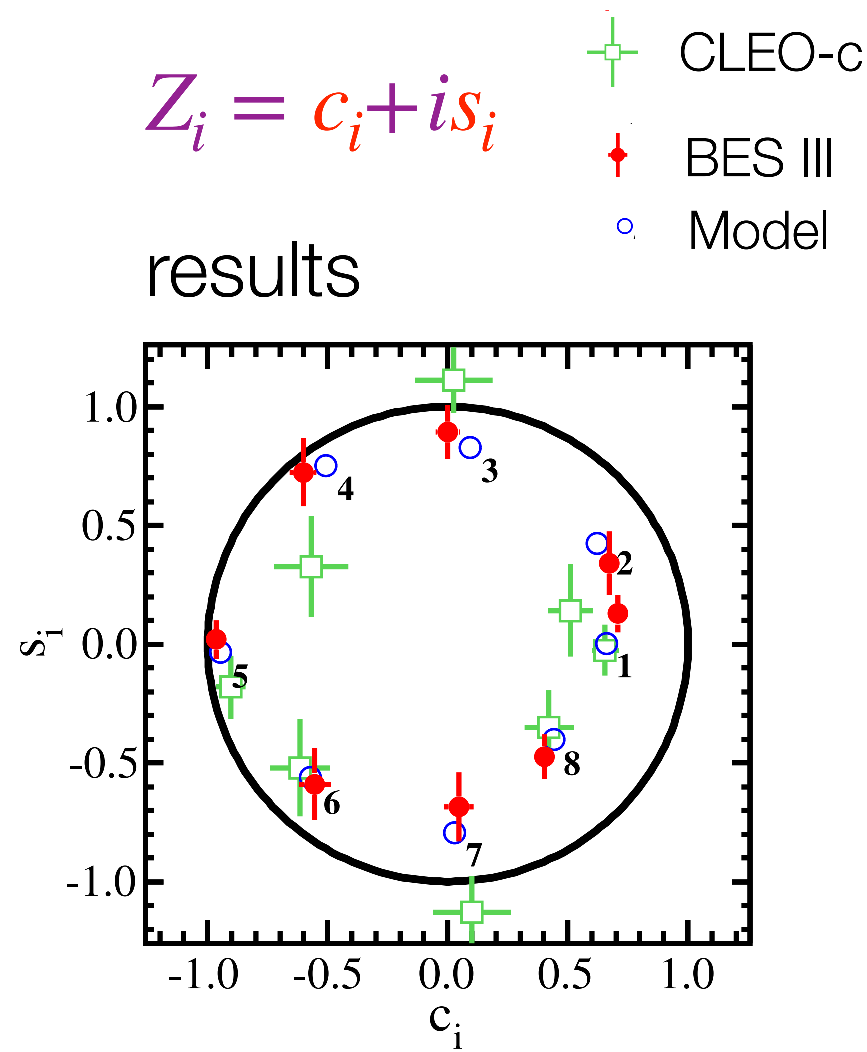
$$D^0 \to K_S\pi^+\pi^-$$

binning



$$Z_i = c_i + i s_i$$

results



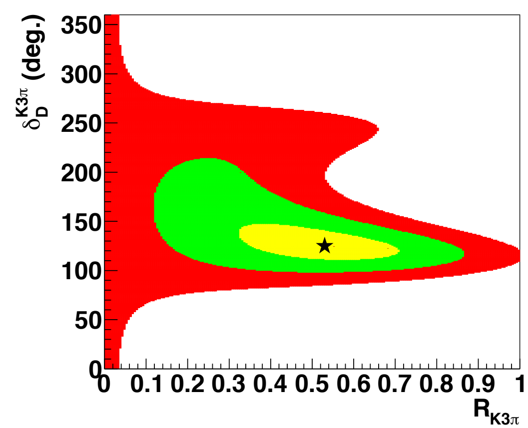
$D^0 \to K^+\pi^-\pi^+\pi^-$ Coherence factor then

Use interference effects in charm as input to γ

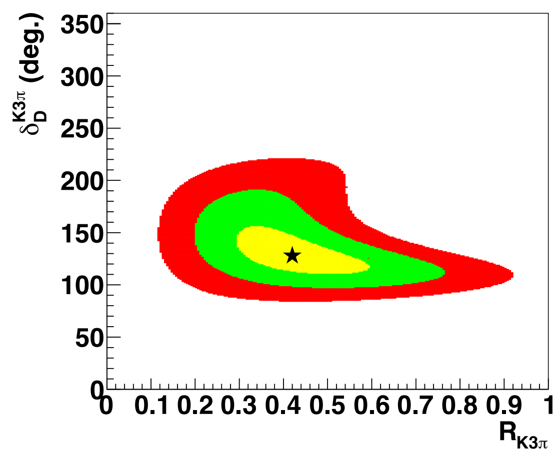
$$Z = R\, e^{-i\delta}$$

$$\Gamma\left(\mathrm{B}^- \to \left(\mathrm{K}^+ 3\pi\right)_{\mathrm{D}} \mathrm{K}^-\right) \propto r_B^2 + \left(r_D^{K3\pi}\right)^2 + 2 R_{K3\pi} r_B r_D^{K3\pi} \cdot \cos\left(\delta_B + \delta_D^{K3\pi} - \gamma\right)$$

CLEO-c data. 2016



Combined with LHCb mixing (Run I)



$\Delta\chi^2$=1,2,4

CLEO-c data: Phys.Lett. B757 (2016) 520-527
Phys.Rev.D80:031105,2009

LHCb: PRL 116 (2016) no.24, 241801

CLEO-c input theory: PRD D68 (2003) 033003
LHCb input theory: Phys.Lett. B728 (2014) 296-302

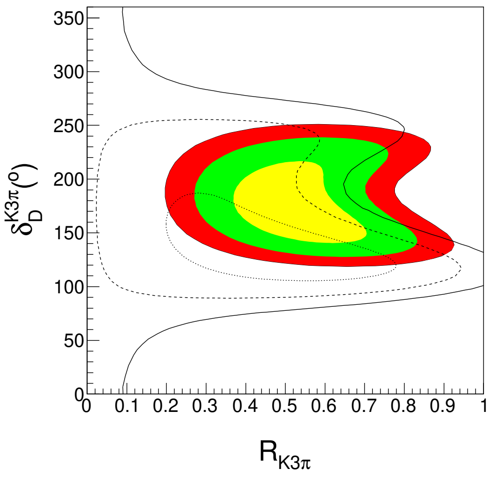
$D^0 \to K^+\pi^-\pi^+\pi^-$ Coherence factor now

Use interference effects in charm as input to γ

$$Z = R\, e^{-i\delta}$$

$$\Gamma\left(\mathrm{B}^- \to \left(\mathrm{K}^+ 3\pi\right)_{\mathrm{D}} \mathrm{K}^-\right) \propto r_B^2 + \left(r_D^{K3\pi}\right)^2 + 2 R_{K3\pi} r_B r_D^{K3\pi} \cdot \cos\left(\delta_B + \delta_D^{K3\pi} - \gamma\right)$$

BES III 2021



BESIII: JHEP 05 (2021) 164

$\Delta\chi^2$=2.3,6.2,11.8 (!)

corresponds to 68%, 95%, 99.7% CL in 2 dimensions

CLEO-c data: Phys.Lett. B757 (2016) 520-527
Phys.Rev.D80:031105,2009

LHCb: PRL 116 (2016) no.24, 241801

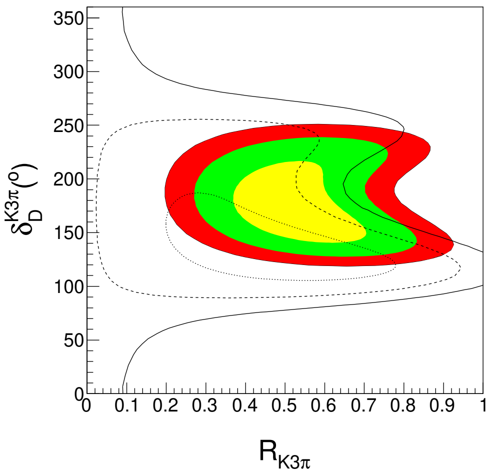
CLEO-c input theory: PRD D68 (2003) 033003
LHCb input theory: Phys.Lett. B728 (2014) 296-302

$D^0 \to K^+\pi^-\pi^+\pi^-$ Coherence factor now

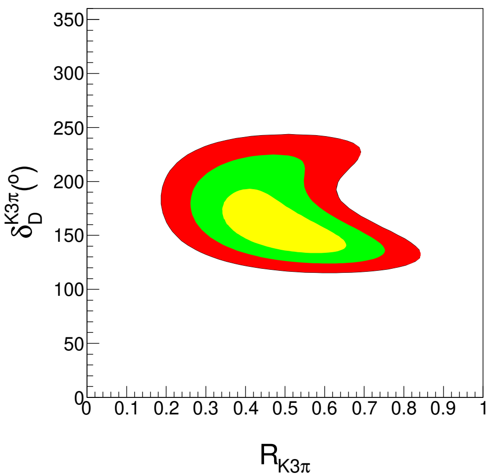
Use interference effects in charm as input to γ $\quad Z = R\,e^{-i\delta}$

$$\Gamma\left(\mathrm{B}^- \to \left(\mathrm{K}^+3\pi\right)_\mathrm{D}\mathrm{K}^-\right) \propto r_B^2 + \left(r_D^{K3\pi}\right)^2 + 2R_{K3\pi}r_Br_D^{K3\pi}\cdot\cos\left(\delta_B + \delta_D^{K3\pi} - \gamma\right)$$

BES III 2021



Combined with CLEO-c



BESIII: JHEP 05 (2021) 164

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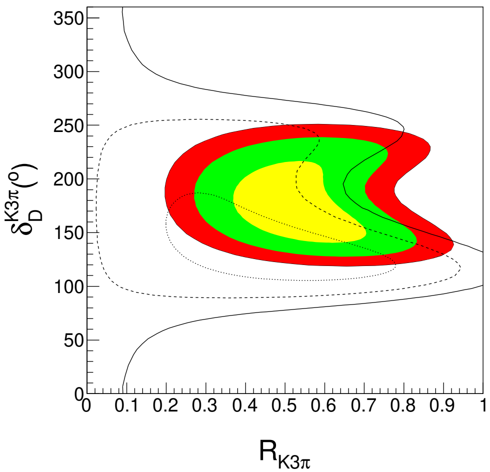
$D^0 \to K^+\pi^-\pi^+\pi^-$ Coherence factor now

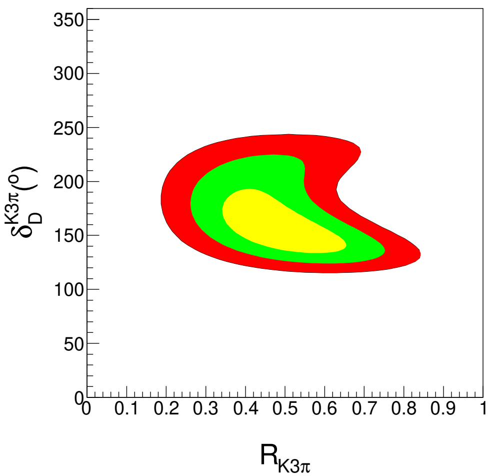
Use interference effects in charm as input to γ $\qquad Z = R\, e^{-i\delta}$

$$\Gamma\left(\mathrm{B}^- \to \left(\mathrm{K}^+ 3\pi\right)_{\mathrm{D}} \mathrm{K}^-\right) \propto r_B^2 + \left(r_D^{K3\pi}\right)^2 + 2 R_{K3\pi} r_B r_D^{K3\pi} \cdot \cos\left(\delta_B + \delta_D^{K3\pi} - \gamma\right)$$

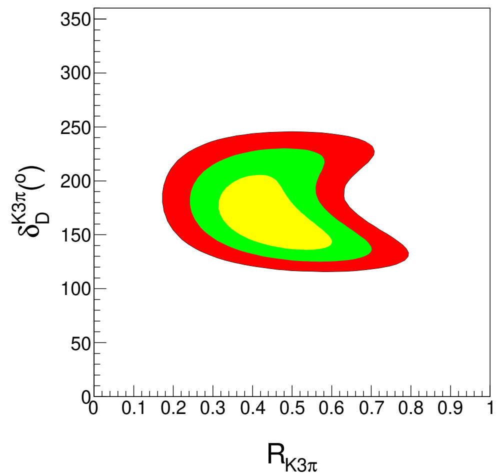
BES III 2021



Combined with CLEO-c



Combined with LHCb mixing (Run I)



BESIII: JHEP 05 (2021) 164

$\Delta\chi^2$=2.3,6.2,11.8 (!)

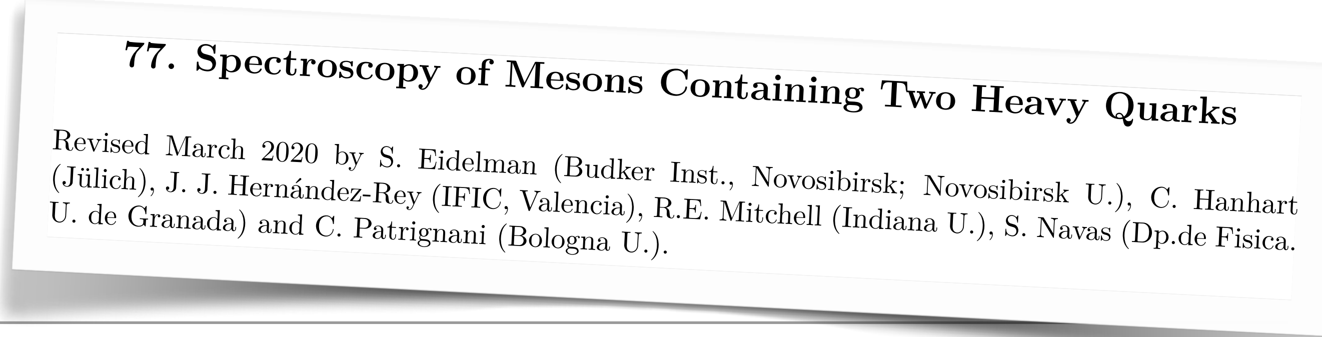
corresponds to 68%, 95%, 99.7% CL in 2 dimensions

CLEO-c data: Phys.Lett. B757 (2016) 520-527
Phys.Rev.D80:031105,2009

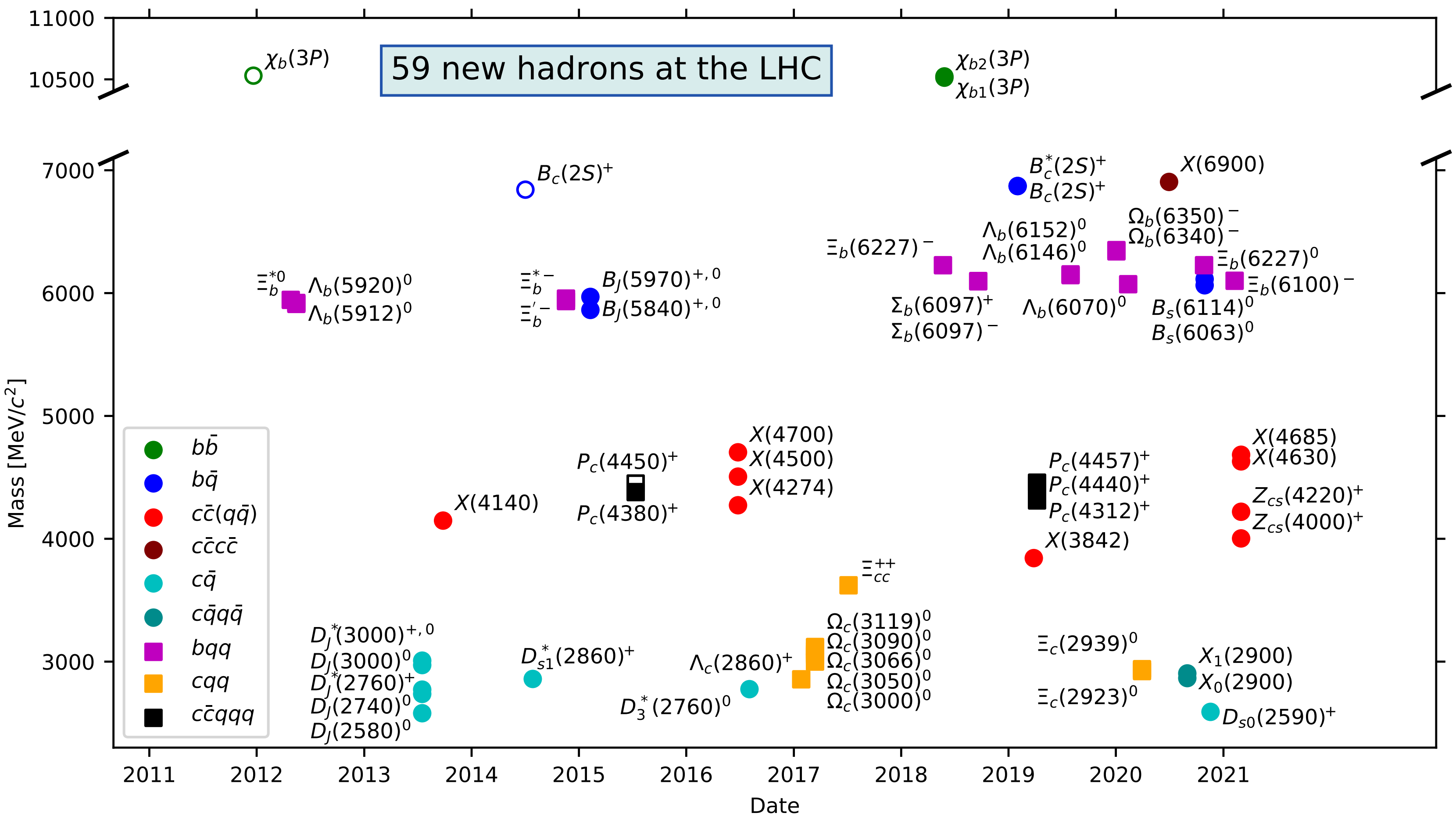
LHCb: PRL 116 (2016) no.24, 241801

CLEO-c input theory: PRD D68 (2003) 033003
LHCb input theory: Phys.Lett. B728 (2014) 296-302

New Particles


77. Spectroscopy of Mesons Containing Two Heavy Quarks

Revised March 2020 by S. Eidelman (Budker Inst., Novosibirsk; Novosibirsk U.), C. Hanhart (Jülich), J. J. Hernández-Rey (IFIC, Valencia), R.E. Mitchell (Indiana U.), S. Navas (Dp.de Fisica, U. de Granada) and C. Patrignani (Bologna U.).



Plot by Patrick Koppenburg: https://www.nikhef.nl/~pkoppenb/particles.html

XYZ→$\chi, \psi, Z, \ldots$

8. Naming Scheme for Hadrons

Revised August 2018 by V. Burkert (Jefferson Lab), S. Eidelman (Budker Inst., Novosibirsk; Novosibirsk U.), C. Hanhart (Jülich), E. Klempt (Bonn U.), R.E. Mitchell (Indiana U.), U. Thoma (Bonn U.), L. Tiator (KPH, JGU Mainz) and R.L. Workman (George Washington U.).

$P = (-1)^{L+1},\ C = (-1)^{L+S}$

S=1

S=0

$J^{PC} = \{$	0^{-+}	1^{+-}	1^{--}	0^{++}
	2^{-+}	3^{+-}	2^{--}	1^{++}
	$\vdots$	$\vdots$	$\vdots$	$\vdots$
Minimal quark content				
$u\bar{d}, u\bar{u} - d\bar{d}, d\bar{u}\ (I=1)$	π	b	ρ	a
$d\bar{d} + u\bar{u}$ and/or $s\bar{s}\ (I=0)$	η,η'	h,h'	ω,ϕ	f,f'
$c\bar{c}$	η_c	h_c	ψ^*	χ_c
$b\bar{b}$	η_b	h_b	Υ	χ_b
$I=1$ with $c\bar{c}$	(Π_c)	Z_c	R_c	(W_c)
$I=1$ with $b\bar{b}$	(Π_b)	Z_b	(R_b)	(W_b)

*The J/ψ remains the J/ψ.

Approach: name implies quantum numbers, not quark content.
X reserved for states with unknown quantum numbers.

8. Naming Scheme for Hadrons

Revised August 2018 by V. Burkert (Jefferson Lab), S. Eidelman (Budker Inst., Novosibirsk; Novosibirsk U.), C. Hanhart (Jülich), E. Klempt (Bonn U.), R.E. Mitchell (Indiana U.), U. Thoma (Bonn U.), L. Tiator (KPH, JGU Mainz) and R.L. Workman (George Washington U.).

Meson name translation table

Mesons with complete $I^G J^{PC}$ assignment	
PDG Name	Former Common Name(s)
$\psi_2(3823)^*$	$X(3823)$
$\chi_{c1}(3872)$	$X(3872)$
$Z_c(3900)$	$Z_c(3900)$
$\chi_{c2}(3930)^\dagger$	$\chi_{c2}(2P)$, $Z(3930)$
$\chi_{c1}(4140)$	$Y(4140)$
$Z_c(4200)$	$Z_c(4200)$
$\psi(4230)$	$Y(4230)$
$R_{c0}(4240)$	$Z_c(4240)$
$\psi(4260)$	$Y(4260)$
$\chi_{c1}(4274)$	$Y(4274)$
$\psi(4360)$	$Y(4360)$
$Z_c(4430)$	$Z_c(4430)$
$\chi_{c0}(4500)$	$X(4500)$
$\psi(4660)$	$X(4630)$, $Y(4660)$
$\chi_{c0}(4700)$	$X(4700)$
$Z_b(10610)$	$Z_b(10610)$
$Z_b(10650)$	$Z_b^{(\prime)}(10650)$

Mesons with incomplete $I^G J^{PC}$ assignment	
PDG Name	Former Common Name(s)
$X(3915)^\ddagger$	$\chi_{c0}(3915)$, $X(3915)$, $Y(3940)$
$X(3940)$	$X(3940)$
$X(4020)$	$Z_c^{(\prime)}(4020)$
$X(4050)^\pm$	$Z_1(4050)$
$X(4055)^\pm$	$Z_c(4055)$
$X(4160)$	$X(4160)$
$X(4250)^\pm$	$Z_2(4250)$
$X(4350)$	$X(4350)$

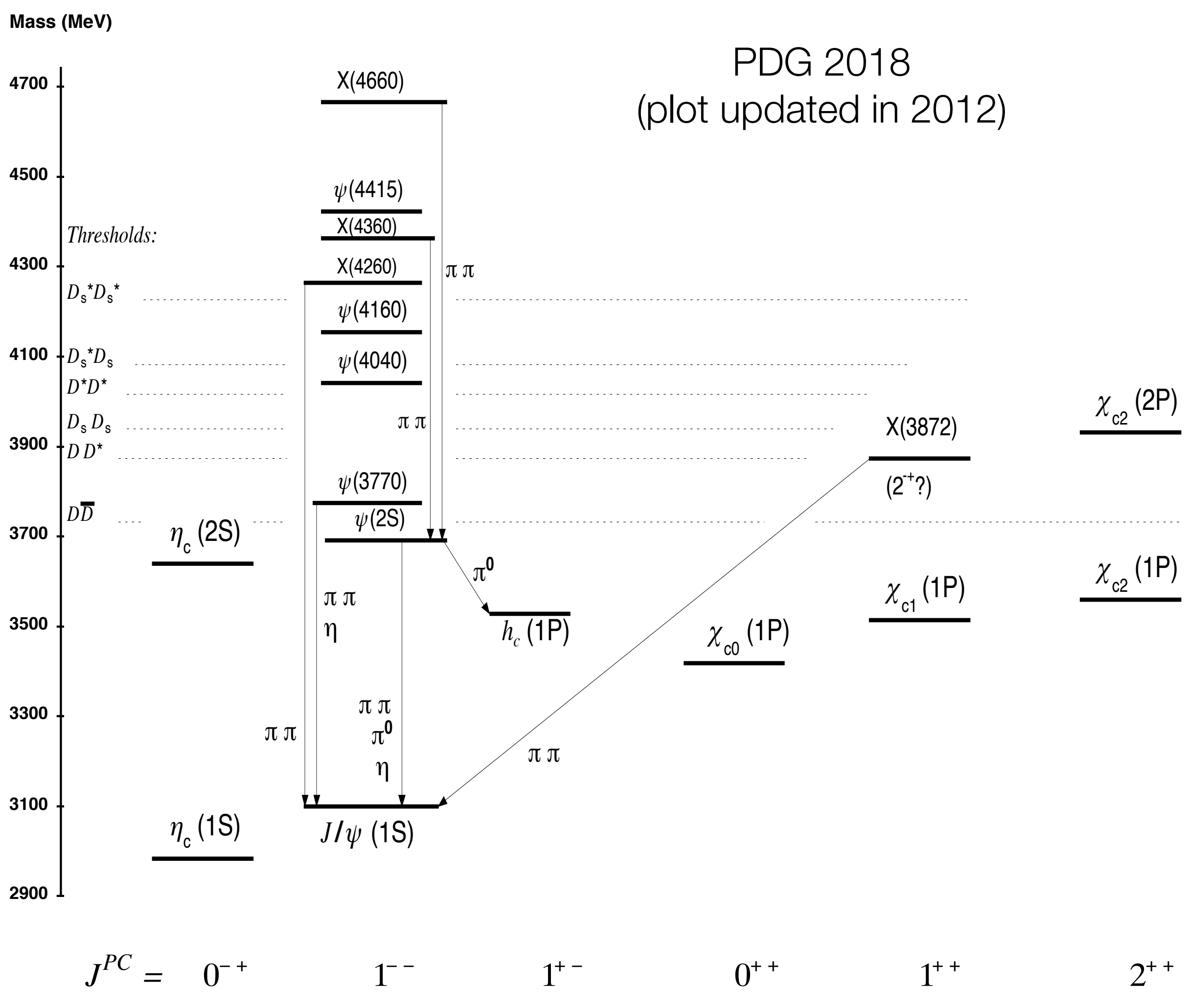
Citation: P.A. Zyla *et al.* (Particle Data Group), Prog. Theor. Exp. Phys. **2020**, 083C01 (2020)

$\boxed{\chi_{c1}(3872)}$ $I^G(J^{PC}) = 0^+(1^{++})$

also known as $X(3872)$

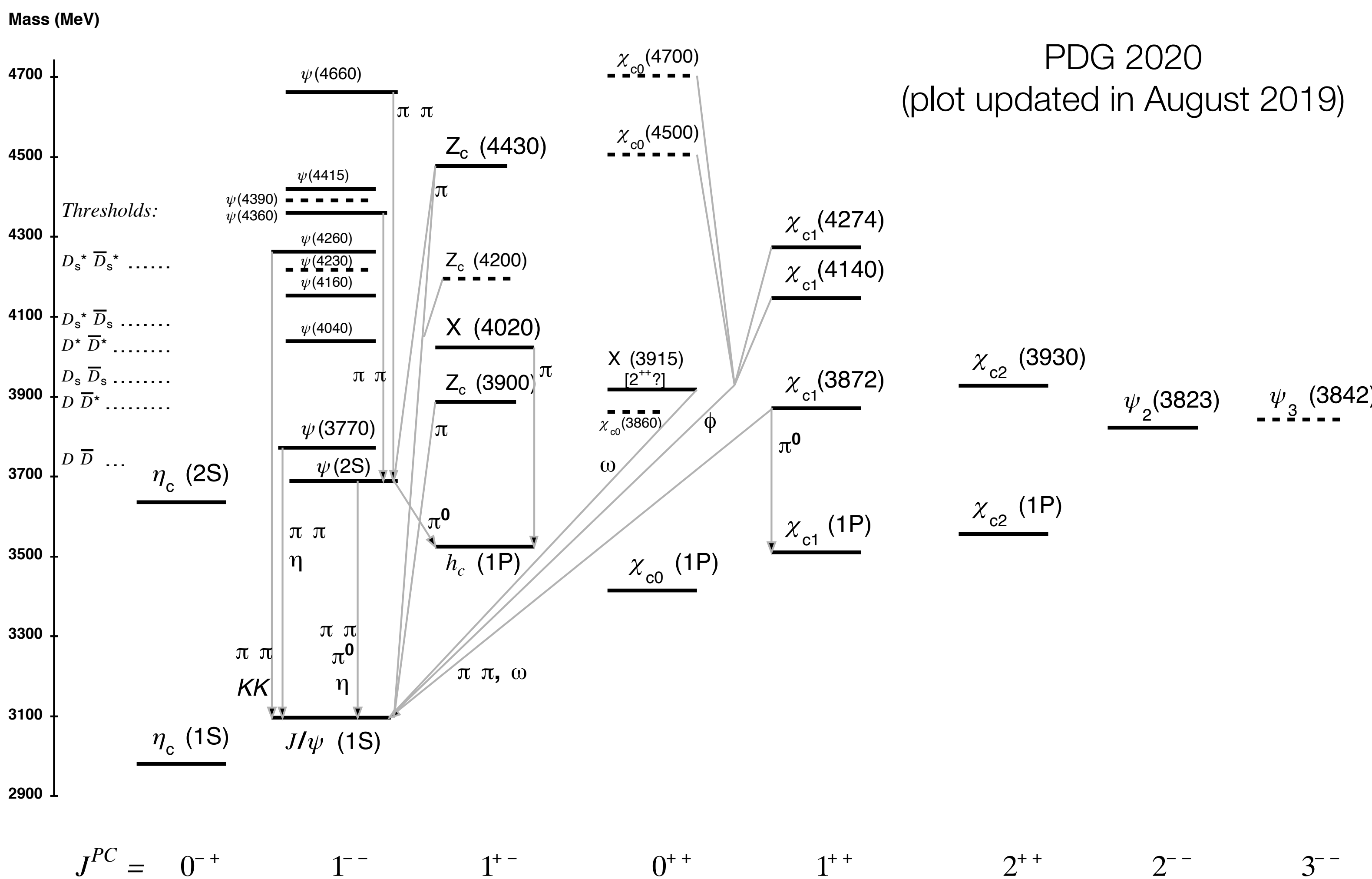
This state shows properties different from a conventional $q\overline{q}$ state.
A candidate for an exotic structure. See the review on non-$q\overline{q}$ states.

Charmonium



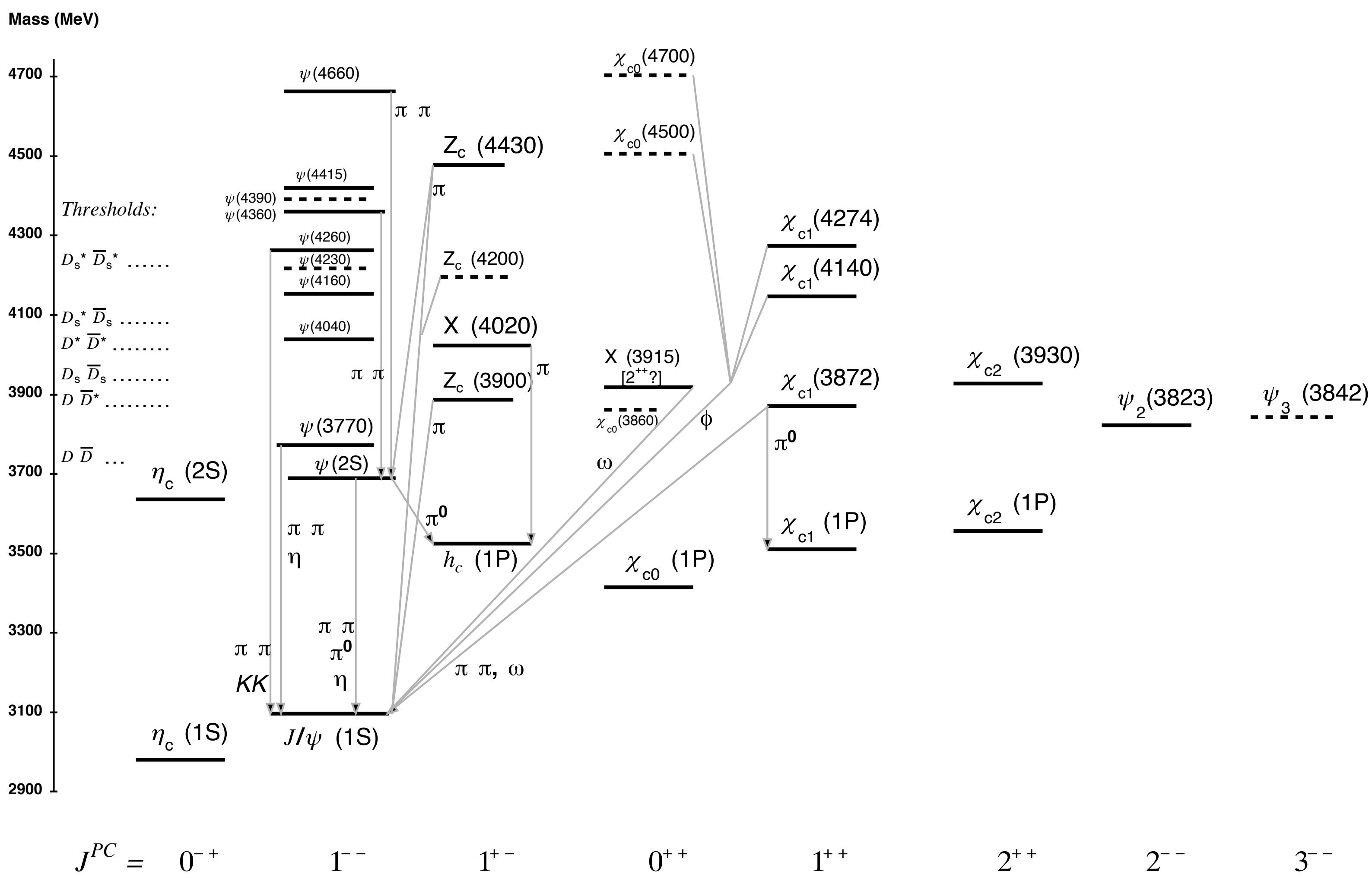
Mass (MeV)
4700
4500
4300
4100
3900
3700
3500
3300
3100
2900
PDG 2018
(plot updated in 2012)
Thresholds:
$D_s^*D_s^*$
$D_s^*D_s$
D^*D^*
$D_s D_s$
$D D^*$
$D\bar{D}$
X(4660)
ψ(4415)
X(4360)
X(4260)
ψ(4160)
ψ(4040)
ψ(3770)
ψ(2S)
J/ψ (1S)
η_c (2S)
η_c (1S)
h_c (1P)
χ_{c0} (1P)
χ_{c1} (1P)
χ_{c2} (1P)
χ_{c2} (2P)
X(3872)
(2^{-+}?)
π π
π π
π^0
π π
η
π π
π π
π^0
η
π π
J^{PC} = 0^{-+} 1^{--} 1^{+-} 0^{++} 1^{++} 2^{++}

Charmonium

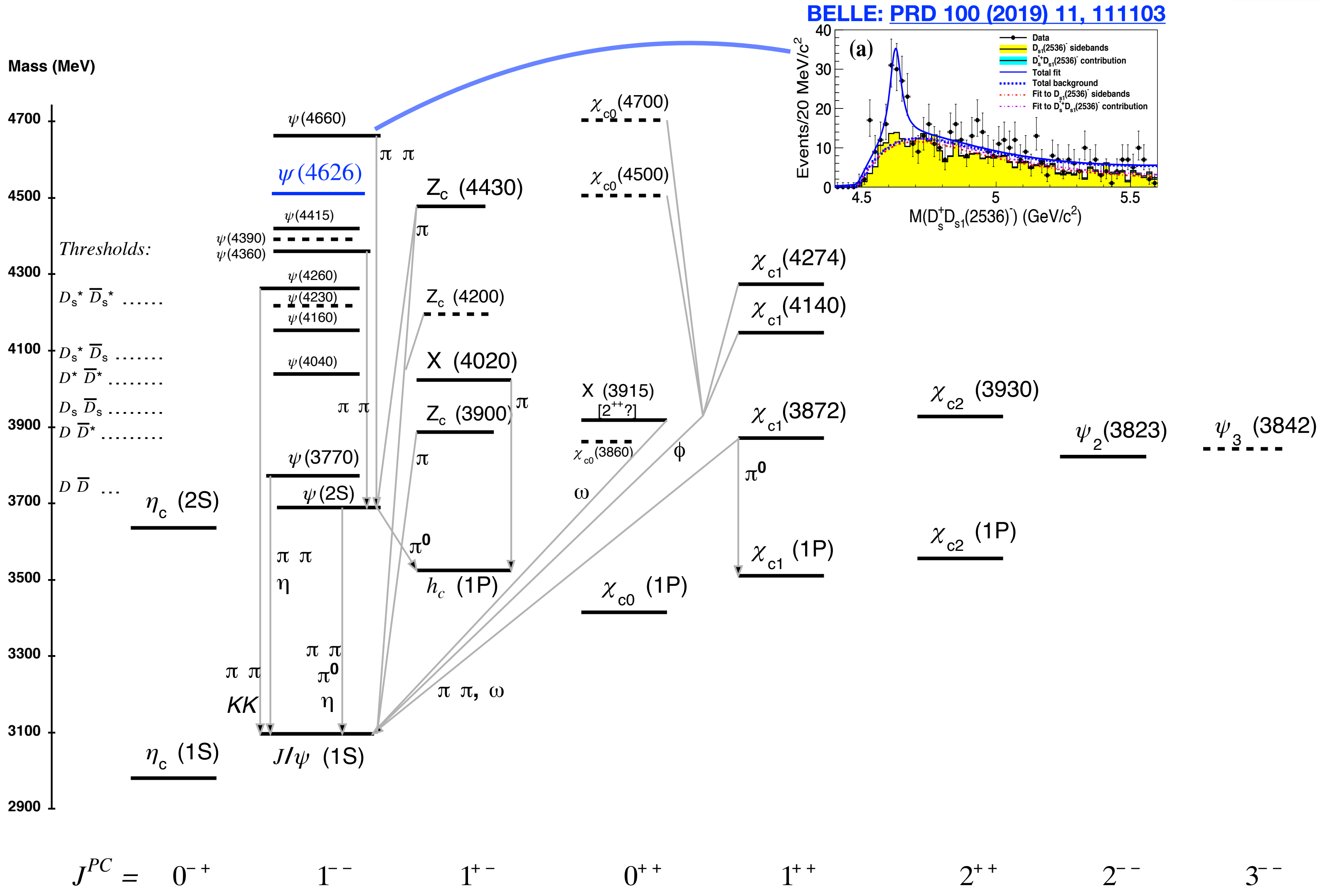


Mass (MeV)
PDG 2020
(plot updated in August 2019)
Thresholds:
ψ(4660)
ψ(4415)
ψ(4390)
ψ(4360)
ψ(4260)
ψ(4230)
ψ(4160)
ψ(4040)
ψ(3770)
ψ(2S)
J/ψ (1S)
η_c (2S)
η_c (1S)
Z_c (4430)
Z_c (4200)
X (4020)
Z_c (3900)
h_c (1P)
χ_c0(4700)
χ_c0(4500)
X (3915)
[2++?]
χ_c0(3860)
χ_c0 (1P)
χ_c1(4274)
χ_c1(4140)
χ_c1(3872)
χ_c1 (1P)
χ_c2 (3930)
χ_c2 (1P)
ψ_2(3823)
ψ_3 (3842)
J^PC = 0−+ 1−− 1+− 0++ 1++ 2++ 2−− 3−−

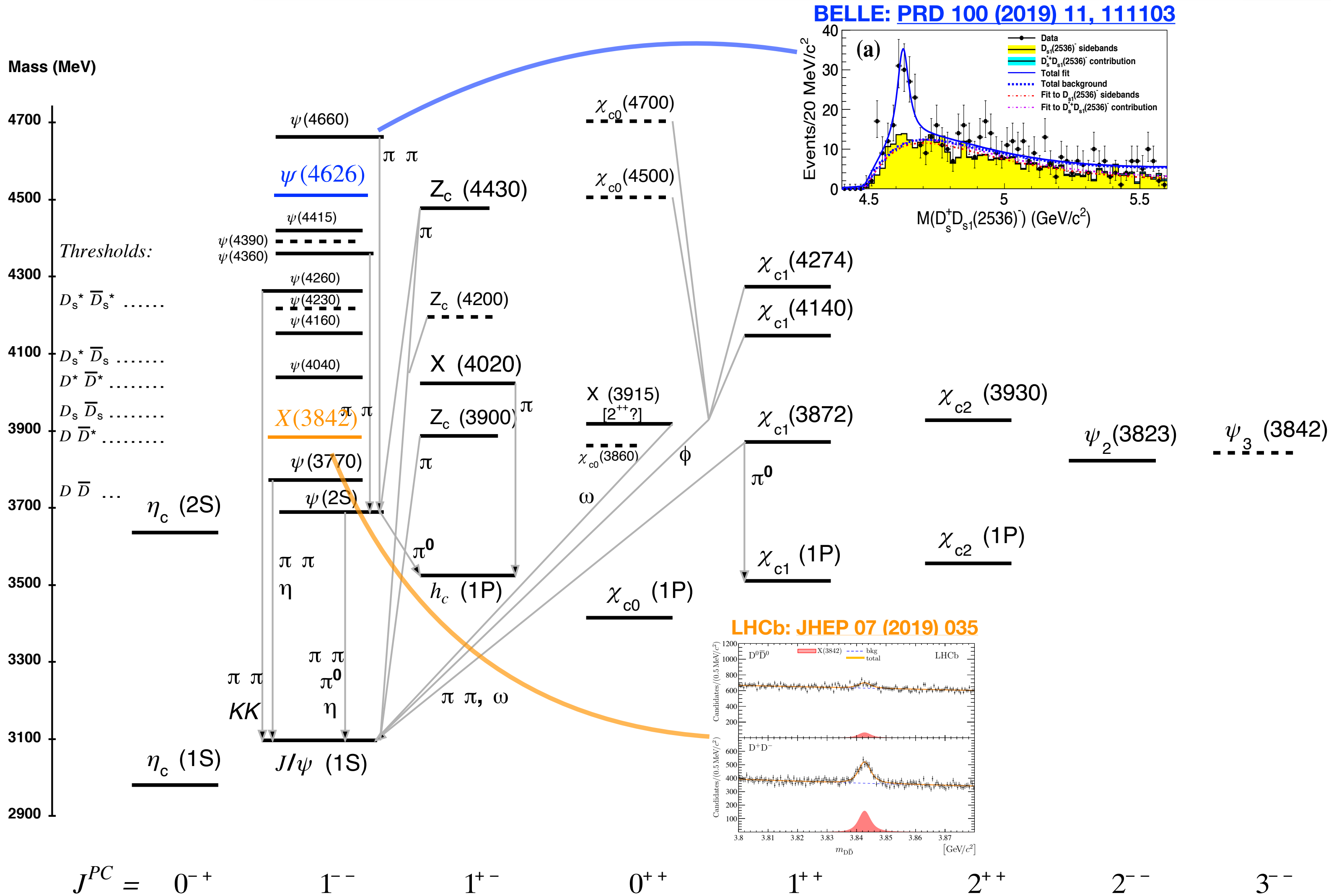
Charmonium


Mass (MeV)
4700
4500
4300
4100
3900
3700
3500
3300
3100
2900
Thresholds:
$D_s^* \overline{D}_s^*$
$D_s^* \overline{D}_s$
$D^* \overline{D}^*$
$D_s \overline{D}_s$
$D \overline{D}^*$
$D \overline{D}$
η_c (2S)
η_c (1S)
ψ(4660)
ψ(4415)
ψ(4390)
ψ(4360)
ψ(4260)
ψ(4230)
ψ(4160)
ψ(4040)
ψ(3770)
ψ(2S)
J/ψ (1S)
Z_c (4430)
Z_c (4200)
X (4020)
Z_c (3900)
h_c (1P)
χ_{c0}(4700)
χ_{c0}(4500)
X (3915)
[2++?]
χ_{c0}(3860)
χ_{c0} (1P)
χ_{c1}(4274)
χ_{c1}(4140)
χ_{c1}(3872)
χ_{c1} (1P)
χ_{c2} (3930)
χ_{c2} (1P)
ψ_2(3823)
ψ_3 (3842)
$\pi\ \pi$
π
π^0
η
KK
ω
ϕ
$\pi\ \pi,\ \omega$
J^{PC} = 0^{-+} 1^{--} 1^{+-} 0^{++} 1^{++} 2^{++} 2^{--} 3^{--}

Charmonium

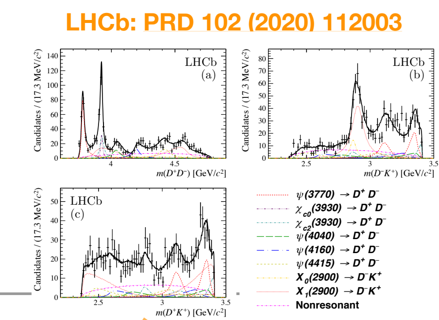

BELLE: PRD 100 (2019) 11, 111103
Mass (MeV)
4700
4500
4300
4100
3900
3700
3500
3300
3100
2900
Thresholds:
$D_s^* \overline{D}_s^*$
$D_s^* \overline{D}_s$
$D^* \overline{D}^*$
$D_s \overline{D}_s$
$D \overline{D}^*$
$D \overline{D}$
η_c (2S)
η_c (1S)
$\psi(4660)$
$\psi(4626)$
$\psi(4415)$
$\psi(4390)$
$\psi(4360)$
$\psi(4260)$
$\psi(4230)$
$\psi(4160)$
$\psi(4040)$
$\psi(3770)$
$\psi(2S)$
J/ψ (1S)
Z_c (4430)
Z_c (4200)
X (4020)
Z_c (3900)
h_c (1P)
$\chi_{c0}(4700)$
$\chi_{c0}(4500)$
X (3915) [2++?]
$\chi_{c0}(3860)$
χ_{c0} (1P)
$\chi_{c1}(4274)$
$\chi_{c1}(4140)$
$\chi_{c1}(3872)$
χ_{c1} (1P)
χ_{c2} (3930)
χ_{c2} (1P)
$\psi_2(3823)$
ψ_3 (3842)
π π
π
π⁰
η
KK
ω
ϕ
π π, ω
J^{PC} = 0^{-+} 1^{--} 1^{+-} 0^{++} 1^{++} 2^{++} 2^{--} 3^{--}
(a)
Events/20 MeV/c²
$M(D_s^+ \bar{D}_{s1}(2536)^-)$ (GeV/c²)
Data
Total fit
Total background

Charmonium

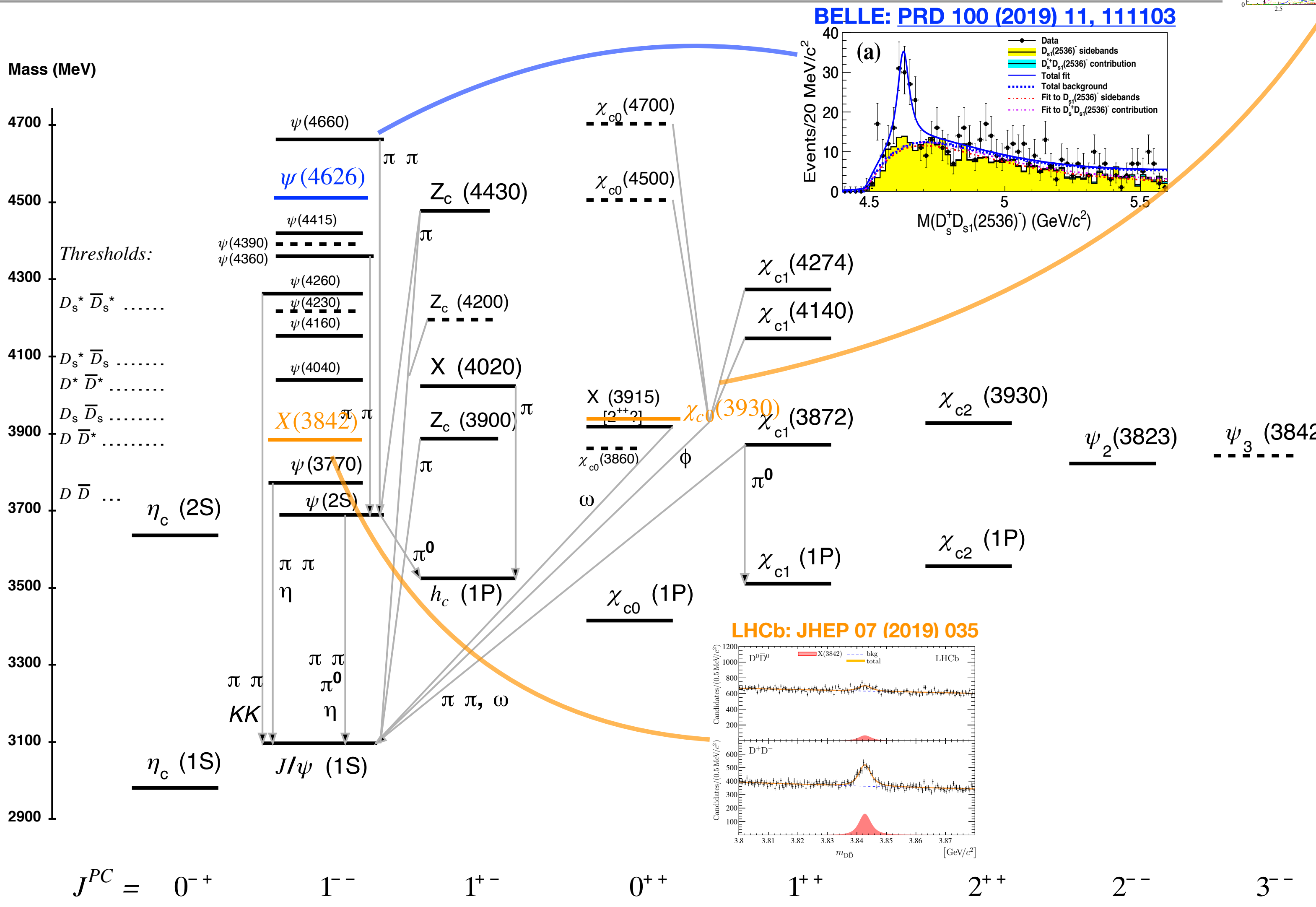


BELLE: PRD 100 (2019) 11, 111103
LHCb: JHEP 07 (2019) 035
Mass (MeV)
4700
4500
4300
4100
3900
3700
3500
3300
3100
2900
Thresholds:
ψ(4660)
ψ(4626)
ψ(4415)
ψ(4390)
ψ(4360)
ψ(4260)
ψ(4230)
ψ(4160)
ψ(4040)
X(3842)
ψ(3770)
ψ(2S)
J/ψ (1S)
η_c (2S)
η_c (1S)
Z_c (4430)
Z_c (4200)
X (4020)
Z_c (3900)
h_c (1P)
χ_c0(4700)
χ_c0(4500)
X (3915)
[2++?]
χ_c0(3860)
χ_c0 (1P)
χ_c1(4274)
χ_c1(4140)
χ_c1(3872)
χ_c1 (1P)
χ_c2 (3930)
χ_c2 (1P)
ψ_2(3823)
ψ_3 (3842)
J^PC = 0−+ 1−− 1+− 0++ 1++ 2++ 2−− 3−−
Events/20 MeV/c^2
M(D_s^+ D_s1(2536)^-) (GeV/c^2)
Data
Total fit
Total background

Charmonium

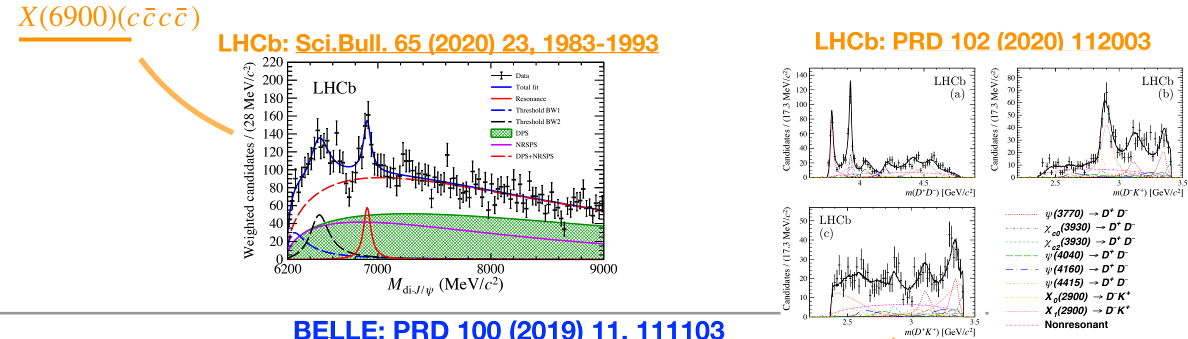


LHCb: PRD 102 (2020) 112003

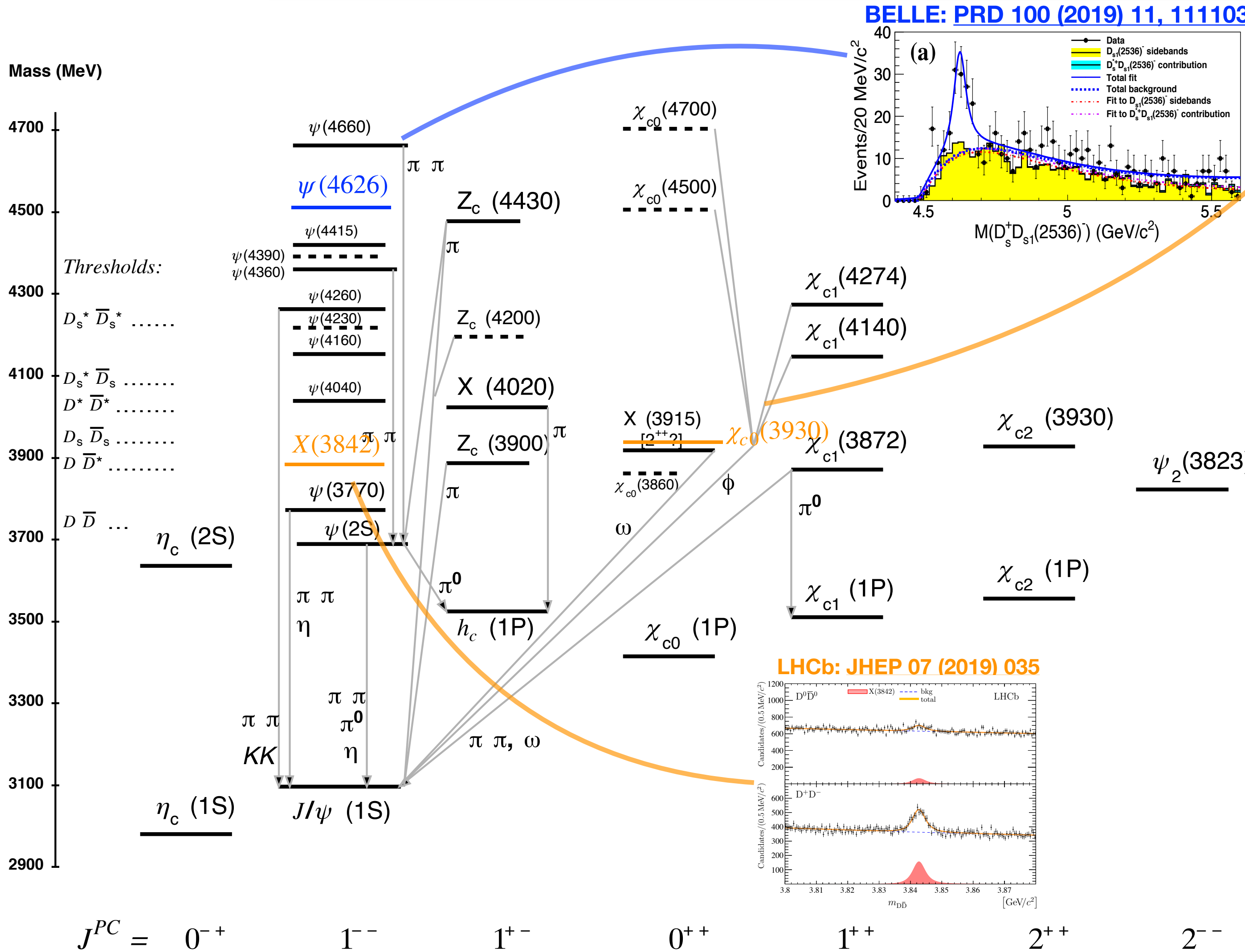


BELLE: PRD 100 (2019) 11, 111103
LHCb: JHEP 07 (2019) 035
Mass (MeV)
4700
4500
4300
4100
3900
3700
3500
3300
3100
2900
Thresholds:
$D_s^* \bar{D}_s^*$
$D_s^* \bar{D}_s$
$D^* \bar{D}^*$
$D_s \bar{D}_s$
$D \bar{D}^*$
$D \bar{D}$
η_c (2S)
η_c (1S)
$\psi(4660)$
$\psi(4626)$
$\psi(4415)$
$\psi(4390)$
$\psi(4360)$
$\psi(4260)$
$\psi(4230)$
$\psi(4160)$
$\psi(4040)$
$X(3842)$
$\psi(3770)$
$\psi(2S)$
J/ψ (1S)
Z_c (4430)
Z_c (4200)
X (4020)
Z_c (3900)
h_c (1P)
$\chi_{c0}(4700)$
$\chi_{c0}(4500)$
X (3915) [2^{++}?]
$\chi_{c0}(3930)$
$\chi_{c0}(3860)$
χ_{c0} (1P)
$\chi_{c1}(4274)$
$\chi_{c1}(4140)$
$\chi_{c1}(3872)$
χ_{c1} (1P)
χ_{c2} (3930)
χ_{c2} (1P)
$\psi_2(3823)$
ψ_3 (3842)
J^{PC} = 0^{-+} 1^{--} 1^{+-} 0^{++} 1^{++} 2^{++} 2^{--} 3^{--}

Charmonium

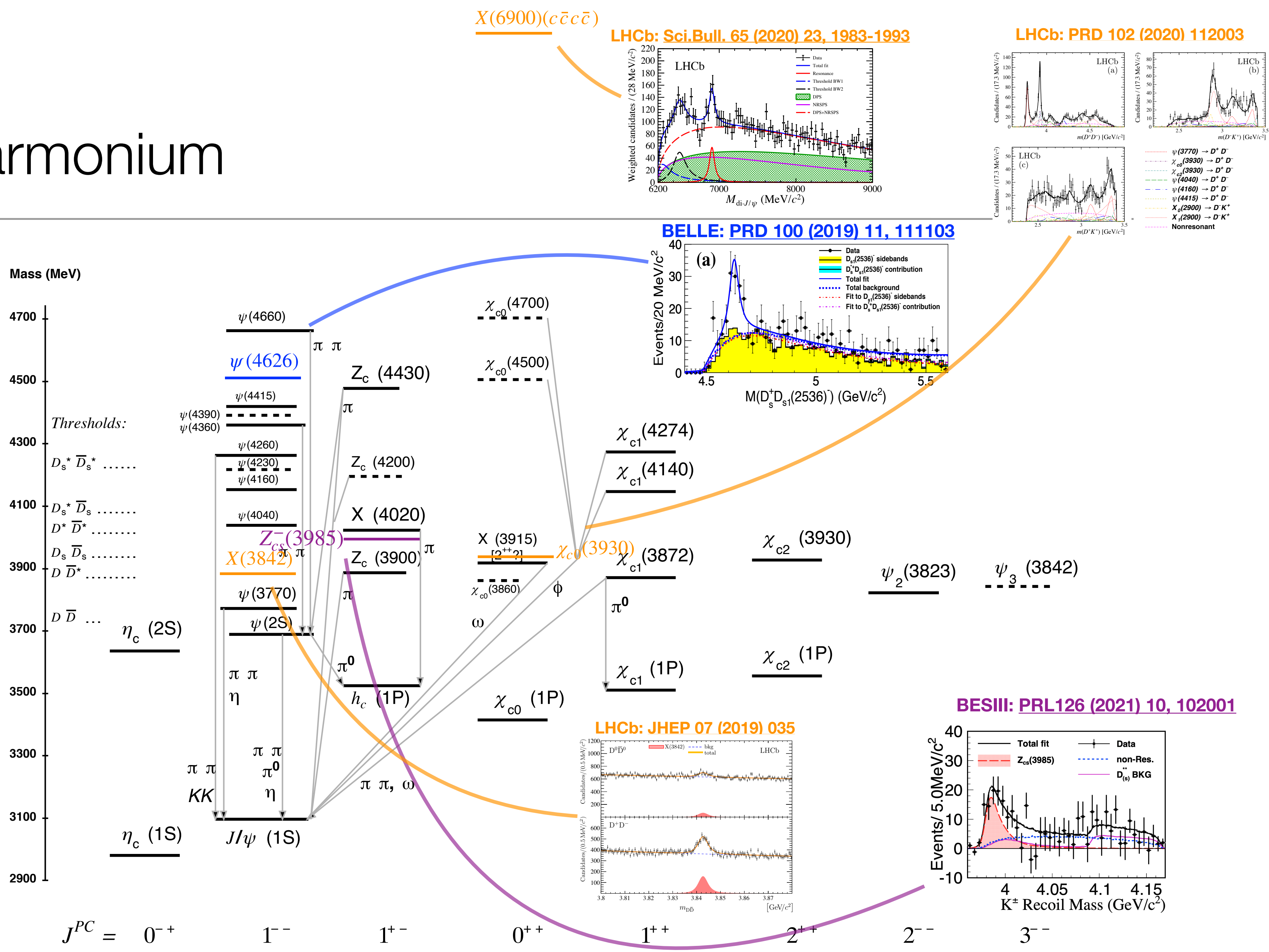


X(6900)(cc̄cc̄)
LHCb: Sci.Bull. 65 (2020) 23, 1983-1993
LHCb: PRD 102 (2020) 112003



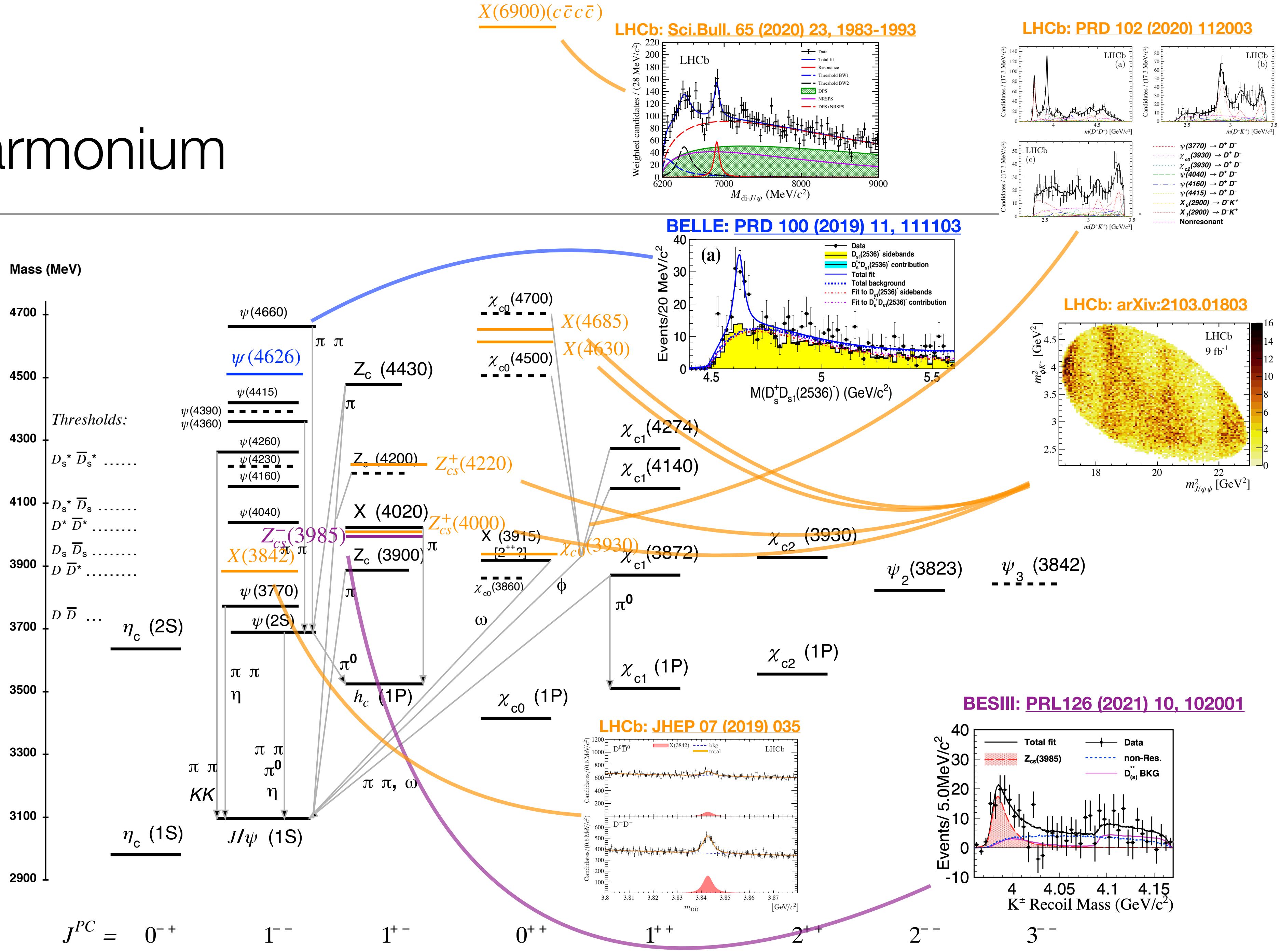
BELLE: PRD 100 (2019) 11, 111103
LHCb: JHEP 07 (2019) 035
Mass (MeV)
4700
4500
4300
4100
3900
3700
3500
3300
3100
2900
Thresholds:
$D_s^* \overline{D}_s^*$
$D_s^* \overline{D}_s$
$D^* \overline{D}^*$
$D_s \overline{D}_s$
$D \overline{D}^*$
$D \overline{D}$
η_c (2S)
η_c (1S)
ψ(4660)
ψ(4626)
ψ(4415)
ψ(4390)
ψ(4360)
ψ(4260)
ψ(4230)
ψ(4160)
ψ(4040)
X(3842)
ψ(3770)
ψ(2S)
J/ψ (1S)
Z_c (4430)
Z_c (4200)
X (4020)
Z_c (3900)
h_c (1P)
χ_{c0}(4700)
χ_{c0}(4500)
X (3915)
[2^{++}?]
χ_{c0}(3930)
χ_{c0}(3860)
χ_{c0} (1P)
χ_{c1}(4274)
χ_{c1}(4140)
χ_{c1}(3872)
χ_{c1} (1P)
χ_{c2} (3930)
χ_{c2} (1P)
ψ_2(3823)
ψ_3 (3842)
J^{PC} = 0^{-+} 1^{--} 1^{+-} 0^{++} 1^{++} 2^{++} 2^{--} 3^{--}

Charmonium



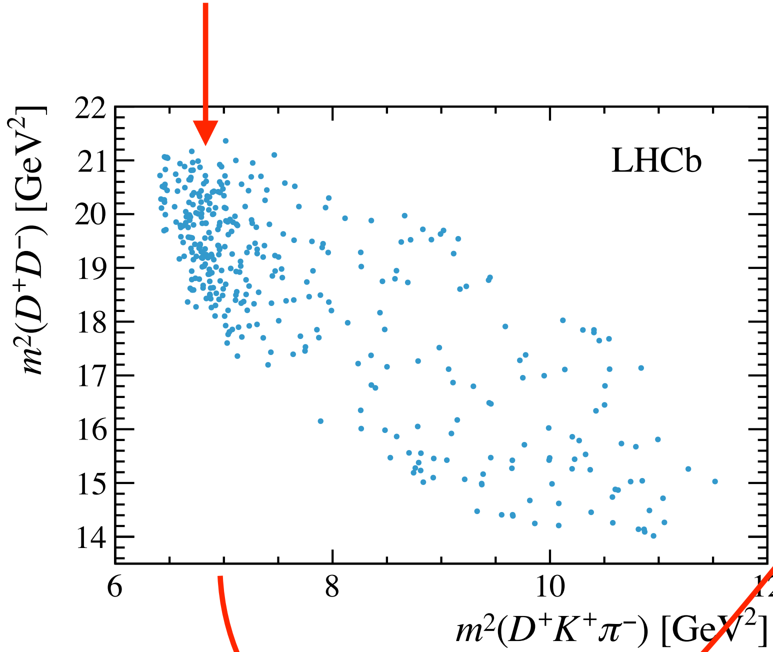
LHCb: Sci.Bull. 65 (2020) 23, 1983-1993
LHCb: PRD 102 (2020) 112003
BELLE: PRD 100 (2019) 11, 111103
LHCb: JHEP 07 (2019) 035
BESIII: PRL126 (2021) 10, 102001
X(6900)(cc̄cc̄)
Mass (MeV)
Thresholds:
ψ(4660)
ψ(4626)
ψ(4415)
ψ(4390)
ψ(4360)
ψ(4260)
ψ(4230)
ψ(4160)
ψ(4040)
X(3842)
ψ(3770)
ψ(2S)
J/ψ (1S)
η_c (2S)
η_c (1S)
Z_c (4430)
Z_c (4200)
X (4020)
Z_cs(3985)
Z_c (3900)
h_c (1P)
χ_c0(4700)
χ_c0(4500)
X (3915)
χ_c0(3930)
χ_c0(3860)
χ_c0 (1P)
χ_c1(4274)
χ_c1(4140)
χ_c1(3872)
χ_c1 (1P)
χ_c2 (3930)
χ_c2 (1P)
ψ_2(3823)
ψ_3 (3842)
J^PC = 0^-+ 1^-- 1^+- 0^++ 1^++ 2^++ 2^-- 3^--

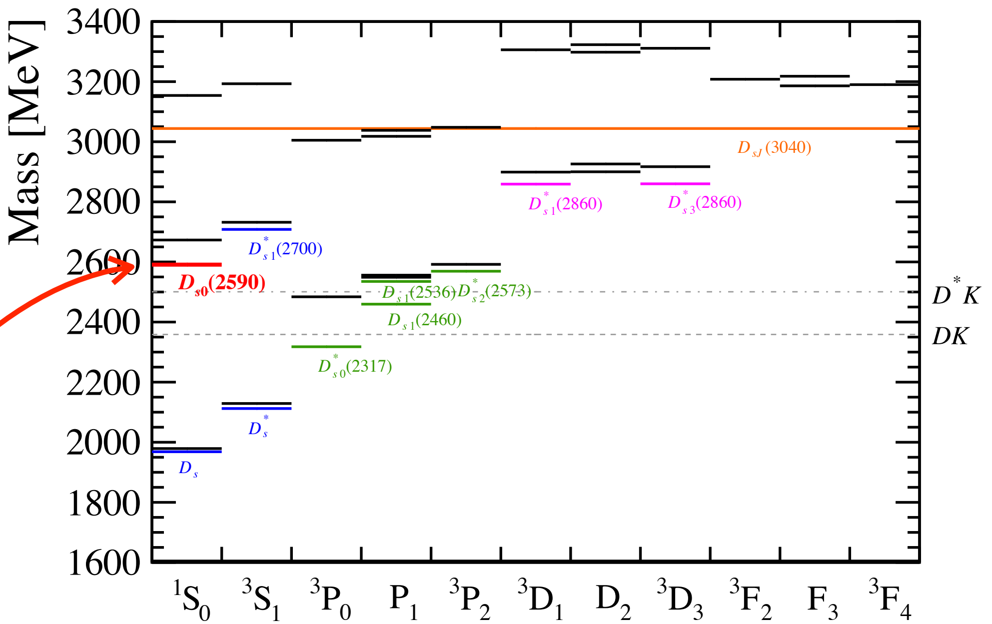
Charmonium



LHCb: Sci.Bull. 65 (2020) 23, 1983-1993
LHCb: PRD 102 (2020) 112003
BELLE: PRD 100 (2019) 11, 111103
LHCb: arXiv:2103.01803
LHCb: JHEP 07 (2019) 035
BESIII: PRL126 (2021) 10, 102001
Mass (MeV)
Thresholds:
X(6900)(cc̄cc̄)
ψ(4660)
ψ(4626)
ψ(4415)
ψ(4390)
ψ(4360)
ψ(4260)
ψ(4230)
ψ(4160)
ψ(4040)
X(3842)
ψ(3770)
ψ(2S)
J/ψ (1S)
η_c (2S)
η_c (1S)
Z_c (4430)
Z_c (4200)
X (4020)
Z_c (3900)
h_c (1P)
Z_cs^-(3985)
Z_cs^+(4220)
Z_cs^+(4000)
χ_c0(4700)
χ_c0(4500)
X(4685)
X(4630)
X (3915)
χ_c0(3930)
χ_c0(3860)
χ_c0 (1P)
χ_c1(4274)
χ_c1(4140)
χ_c1(3872)
χ_c1 (1P)
χ_c2 (3930)
χ_c2 (1P)
ψ_2(3823)
ψ_3 (3842)
J^PC = 0^-+ 1^-- 1^+- 0^++ 1^++ 2^++ 2^-- 3^--

New Charm-Strange





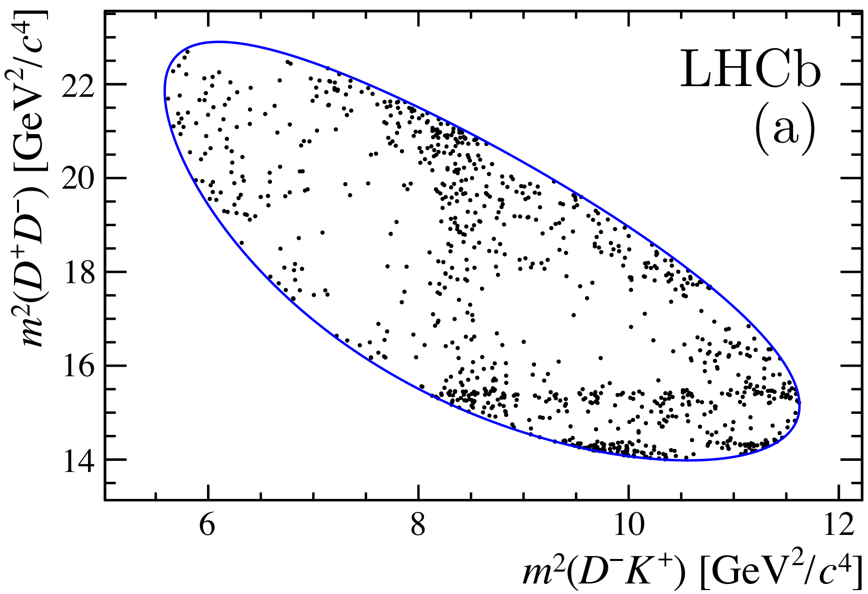
LHCb: PRL 126 (2021) 122002

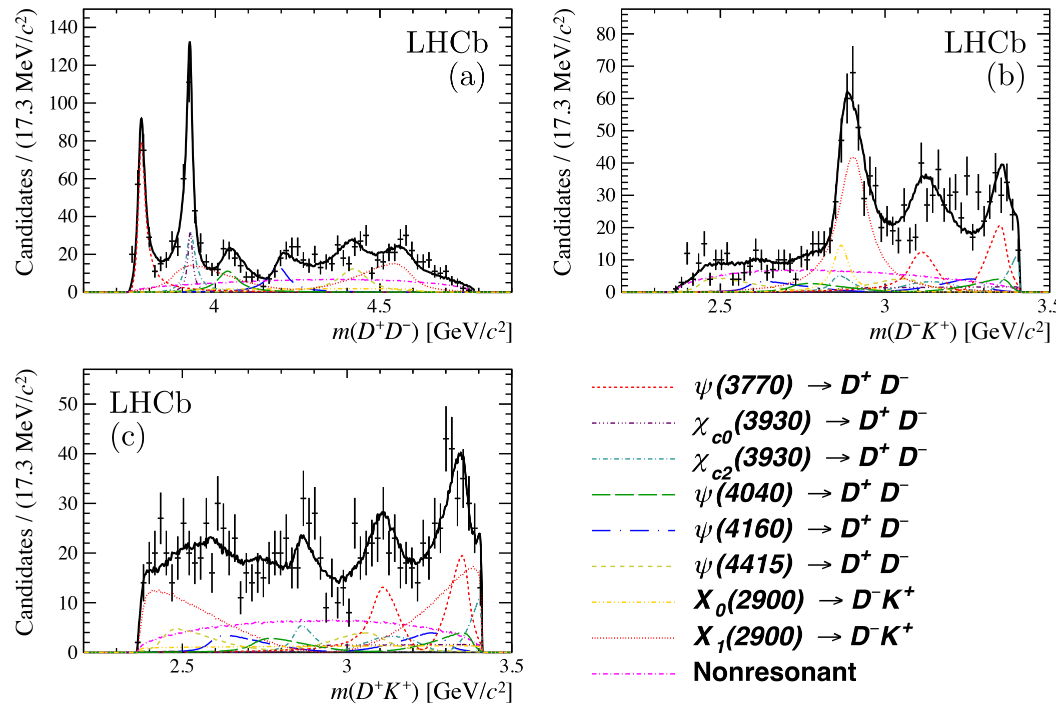
Mellissa Cruz' talk

New really strange: First tetra flavour

LHCb: PRL 125 (2020) 242001
LHCb: PRD 102 (2020) 112003

$B^+ \to D^+D^-K^+$ Dalitz Plot





Best fit with two new D^-K^+resonances, $X_0(2900), X_1(2900)$, which have minimal quark content $\bar{c}d\bar{s}u$.

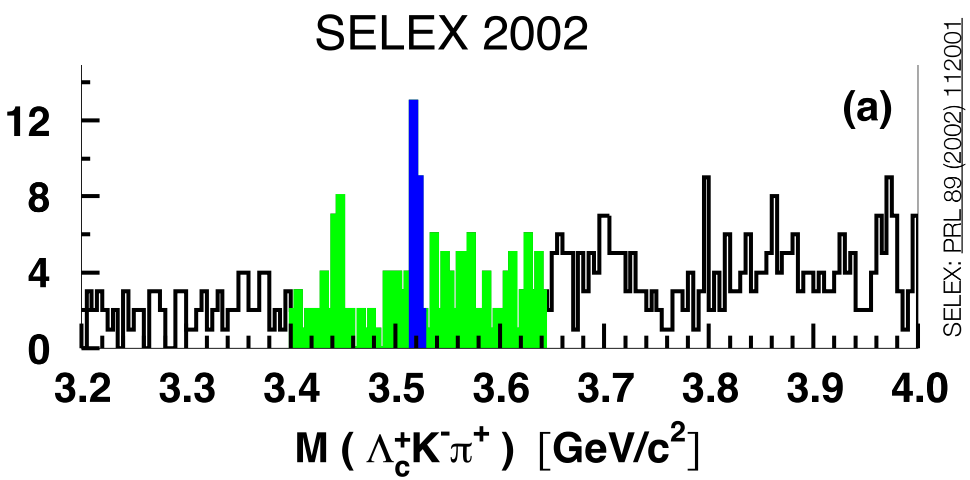
Doubly charmed baryon Ξ_{cc}^{+}?

84. Charmed Baryons

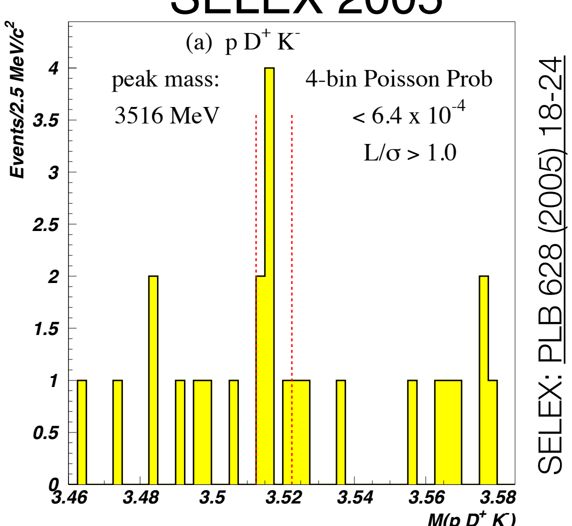
Revised in part June 2020 by D.J. Robinson (LBNL).

SELEX see it twice at 3.5GeV

SELEX 2002



SELEX 2005



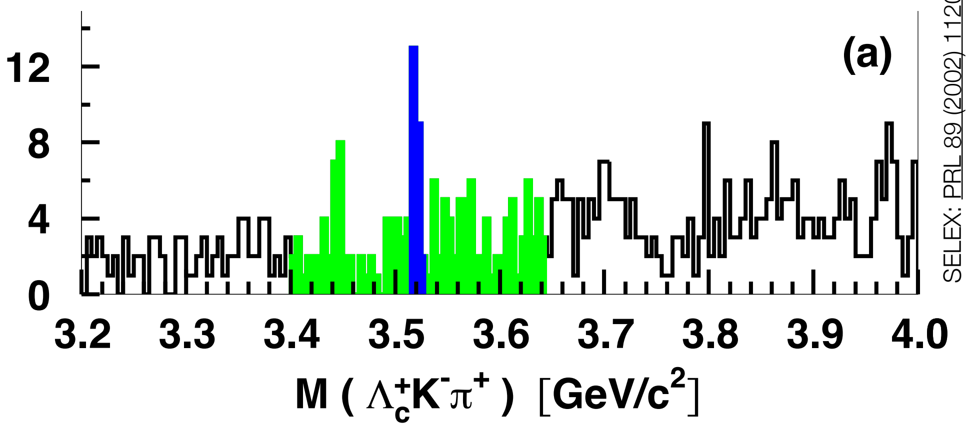
Doubly charmed baryon Ξ_{cc}^{+}?

84. Charmed Baryons

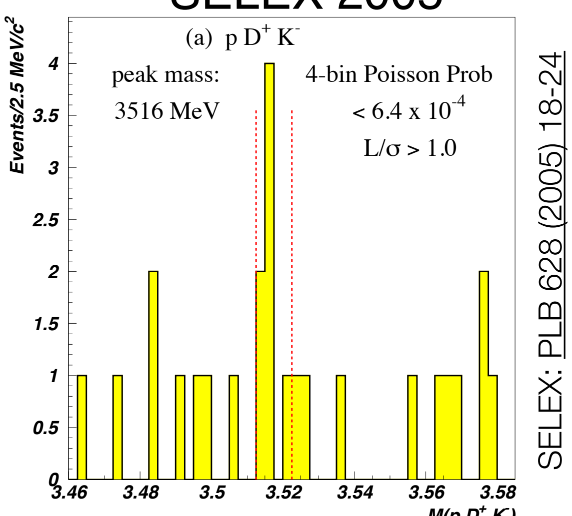
Revised in part June 2020 by D.J. Robinson (LBNL).

SELEX see it twice at 3.5GeV

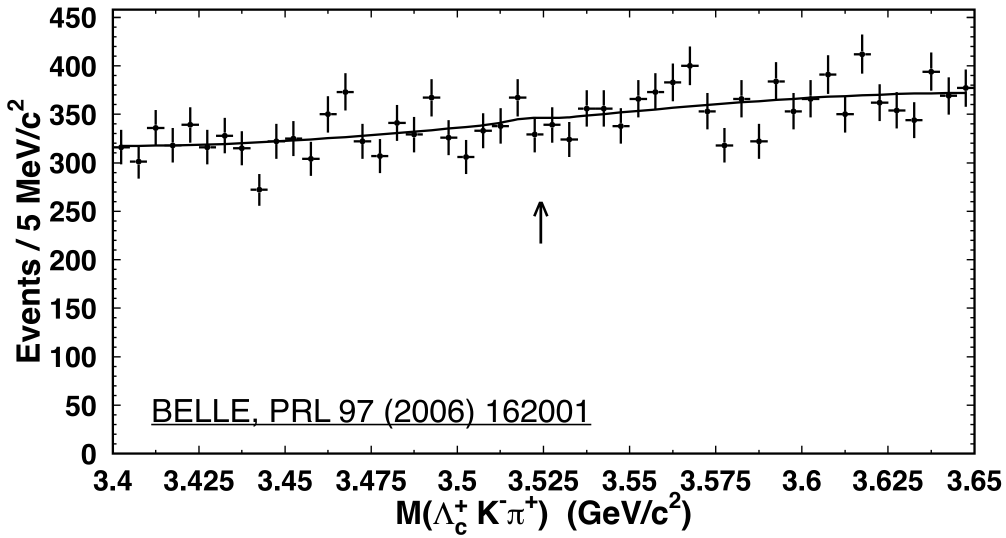
SELEX 2002



SELEX 2005



FOCUS, BaBar, BELLE, LHCb don't



pdg.lbl.gov/2018/listings/rpp2018-list-xicc-plus.pdf

s065.dvi 1 / 2 100%

Citation: M. Tanabashi *et al.* (Particle Data Group), Phys. Rev. D **98**, 030001 (2018)

Ξ_{cc}^{+}

$I(J^P) = ?(?^?)$ Status: *

OMITTED FROM SUMMARY TABLE

This would presumably be an isospin-1/2 particle, a ccu Ξ_{cc}^{++} and a ccd Ξ_{cc}^{+}. However, opposed to the evidence cited below, the BABAR experiment has found no evidence for a Ξ_{cc}^{+} in a search in $\Lambda_c^+ K^- \pi^+$ and $\Xi_c^0 \pi^+$ modes, and no evidence of a Ξ_{cc}^{++} in $\Lambda_c^+ K^- \pi^+ \pi^+$ and $\Xi_c^0 \pi^+ \pi^+$ modes (AUBERT,B 06D). Nor have the BELLE (CHISTOV 06, KATO 14) or LHCb (AAIJ 13CD) experiments found any evidence for this state.

Ξ_{cc}^{+} MASS

VALUE (MeV)	*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
3518.9±0.9 OUR AVERAGE				
3518 ±3	6	[1] OCHERASHVI..05	SELX	Σ^- nucleus ≈ 600 GeV
3519 ±1	16	[2] MATTSON 02	SELX	Σ^- nucleus ≈ 600 GeV

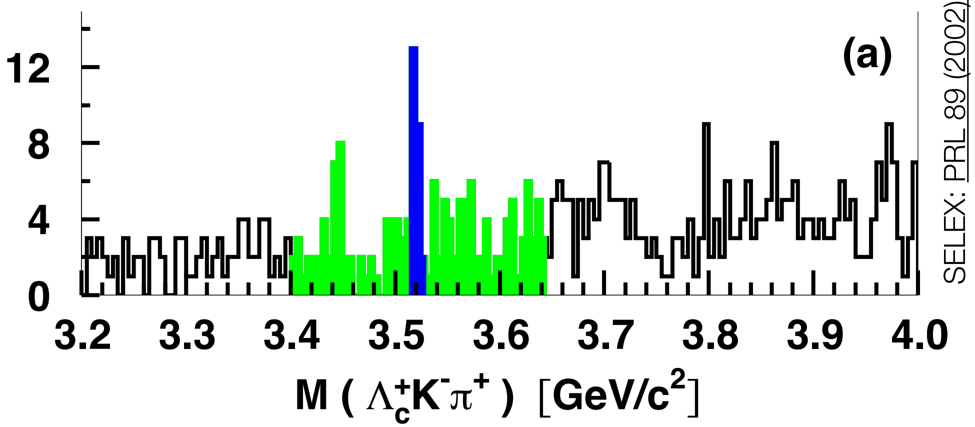
[1] OCHERASHVILI 05 claims "an excess of 5.62 events over ... 1.38 ± 0.13 events" for a significance of 4.8 σ in pD^+K^- events.

[2] MATTSON 02 claims "an excess of 15.9 events over an expected background of 6.1 ± 0.5 events, a statistical significance of 6.3 σ" in the $\Lambda_c^+ K^- \pi^+$ invariant-mass spectrum. The probability that the peak is a fluctuation increases from 1.0×10^{-6} to 1.1×10^{-4} when the number of bins searched is considered.

Ξ_{cc}^{+}?

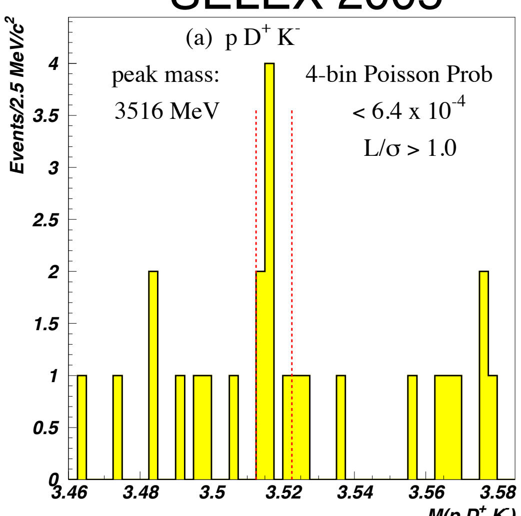
SELEX see it twice

SELEX 2002

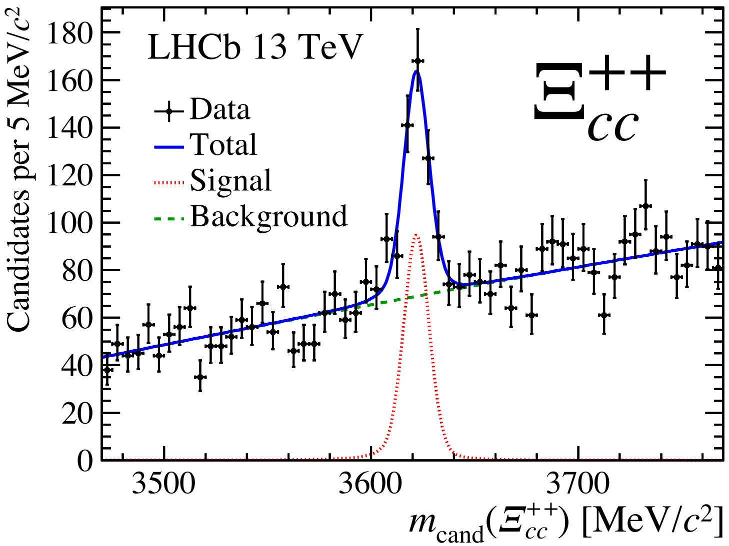


SELEX: PRL 89 (2002) 112001

SELEX 2005



SELEX: PLB 628 (2005) 18-24

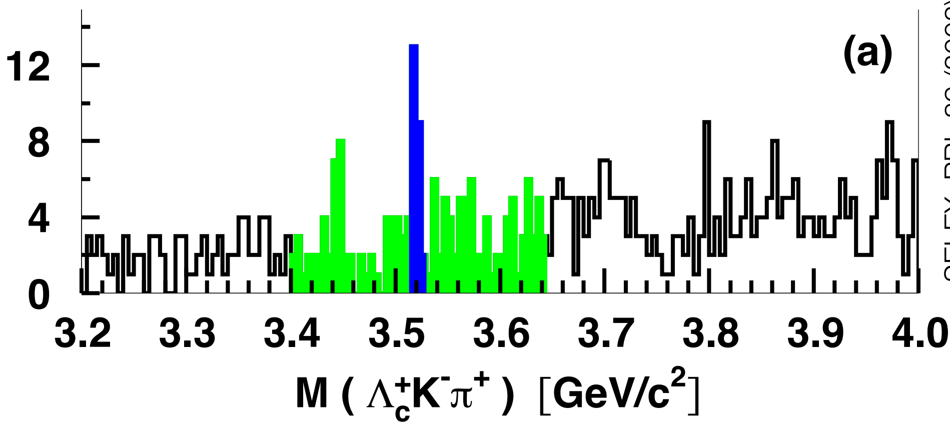


LHCb: JHEP 02 (2020) 049

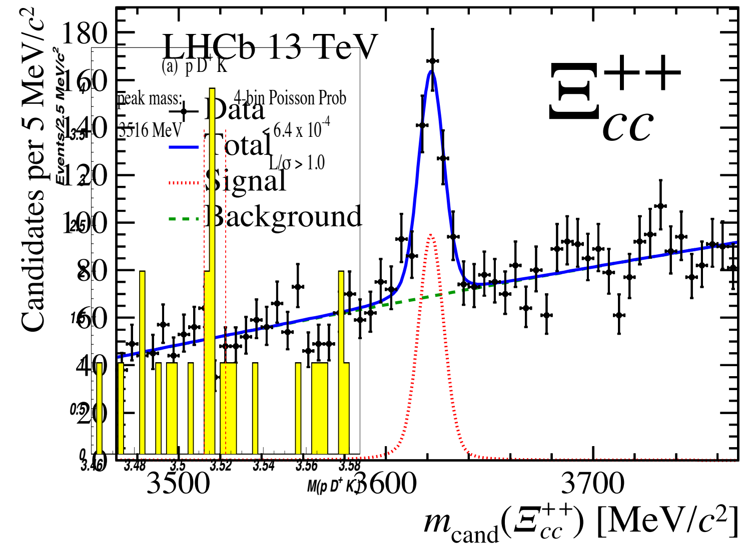
LHCb: PRL 121 (2018) 16, 162002, Chin.Phys.C 44 (2020) 2, 022001, JHEP 02 (2020) 049

Ξ_{cc}^{+}?

SELEX see it twice



SELEX: PRL 89 (2002) 112001



LHCb: JHEP 02 (2020) 049

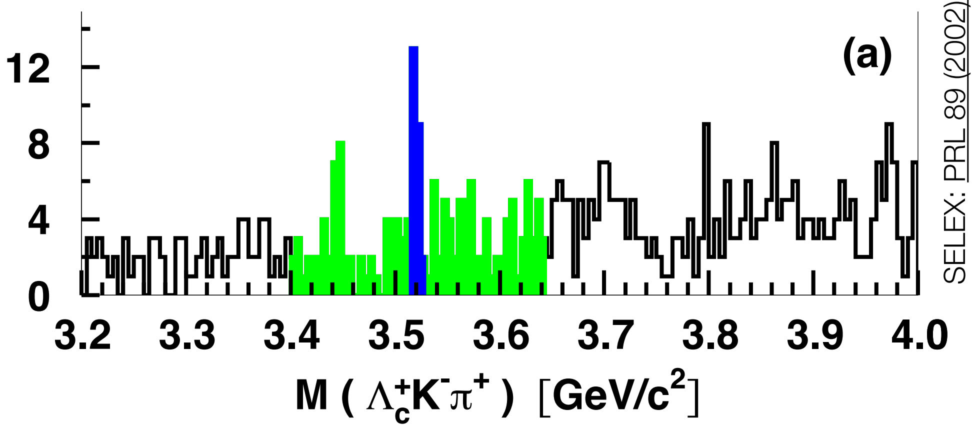
SELEX: PLB 628 (2005) 18-24

LHCb: PRL 121 (2018) 16, 162002, Chin.Phys.C 44 (2020) 2, 022001, JHEP 02 (2020) 049

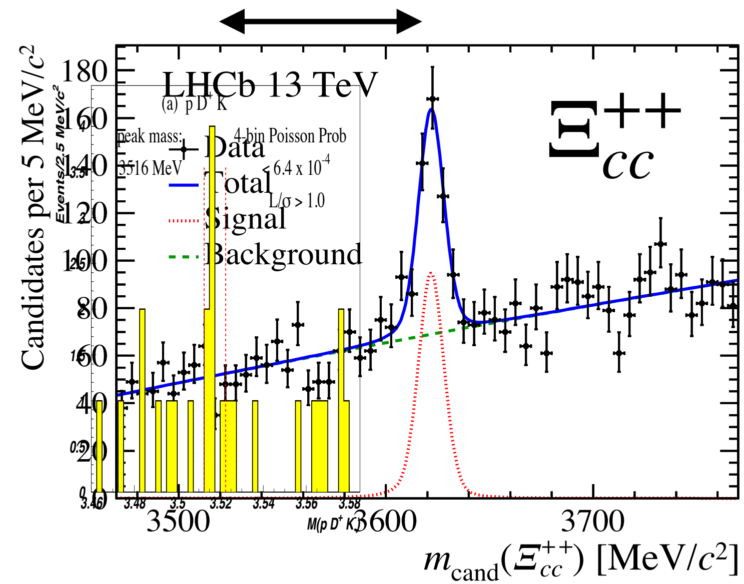
Ξ_{cc}^{+}?

SELEX see it twice

SELEX 2002



SELEX: PRL 89 (2002) 112001



LHCb: JHEP 02 (2020) 049

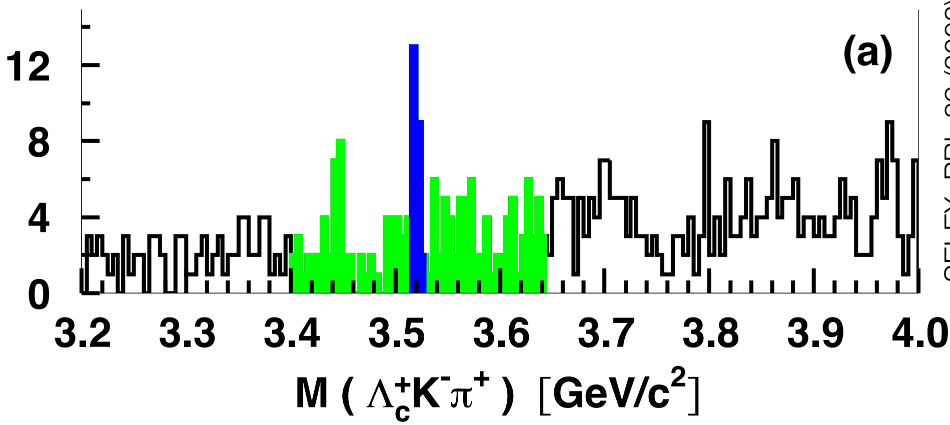
LHCb: PRL 121 (2018) 16, 162002, Chin.Phys.C 44 (2020) 2, 022001, JHEP 02 (2020) 049

SELEX: PLB 628 (2005) 18-24

Ξ_{cc}^{+}?

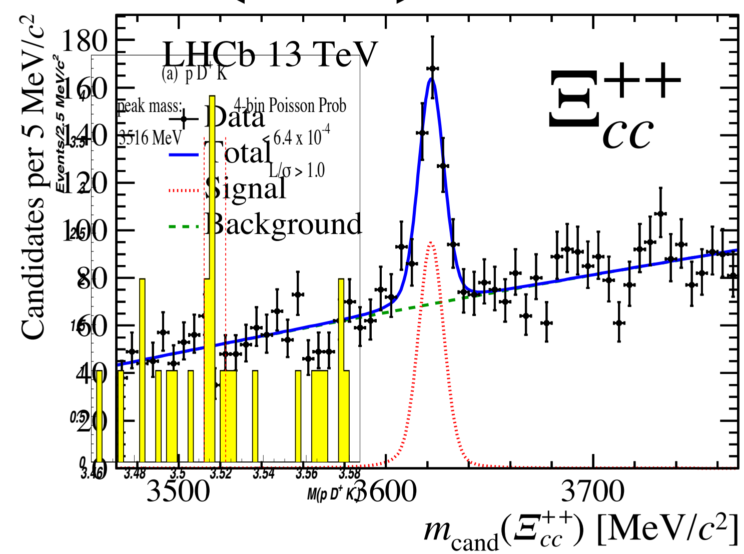
SELEX see it twice

SELEX 2002



SELEX: PRL 89 (2002) 112001

too big for isospin



LHCb: JHEP 02 (2020) 049

LHCb: PRL 121 (2018) 16, 162002, Chin.Phys.C 44 (2020) 2, 022001, JHEP 02 (2020) 049

SELEX: PLB 628 (2005) 18-24

pdg.lbl.gov/2020/listings/rpp2020-list-xicc-plus.pdf

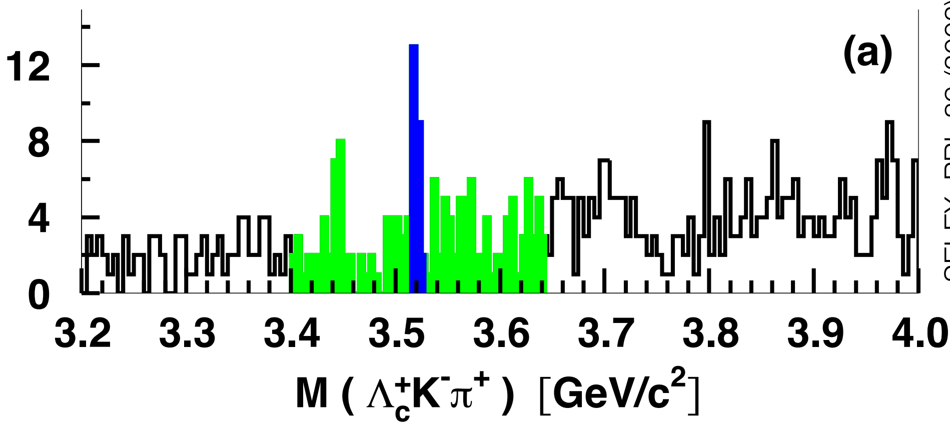
PDG particle data group

404 - We're sorry, the page you are looking for does not exist.

If you were directed here by mistake or think this is a bug, please let us know at **support@pdg.lbl.gov**.
Thank you.

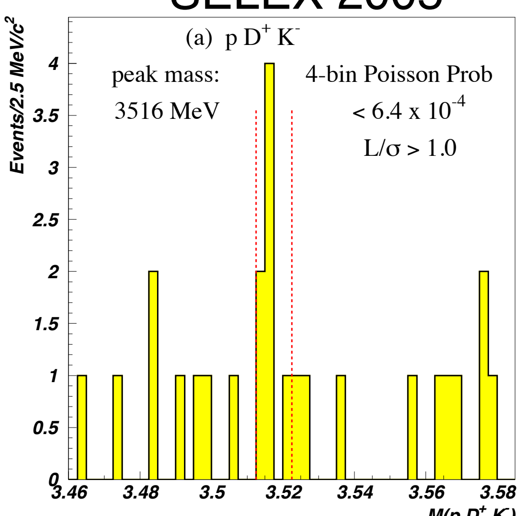
Ξ_{cc}^{+}?

SELEX 2002

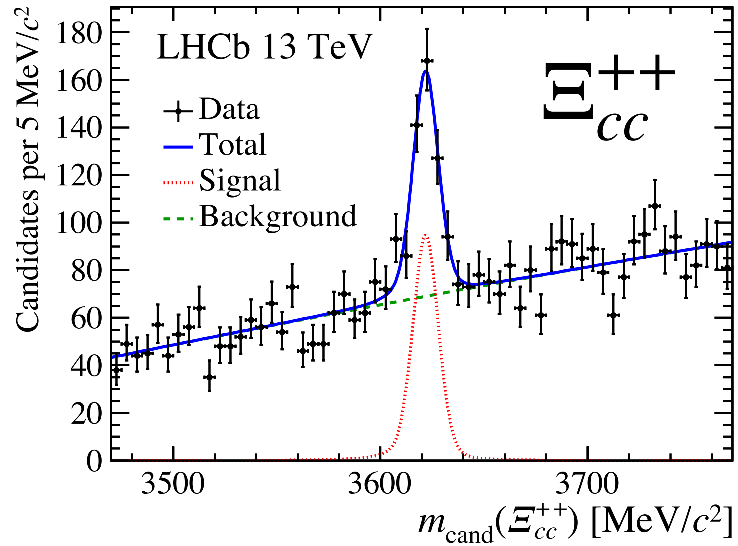


SELEX: PRL 89 (2002) 112001

SELEX 2005



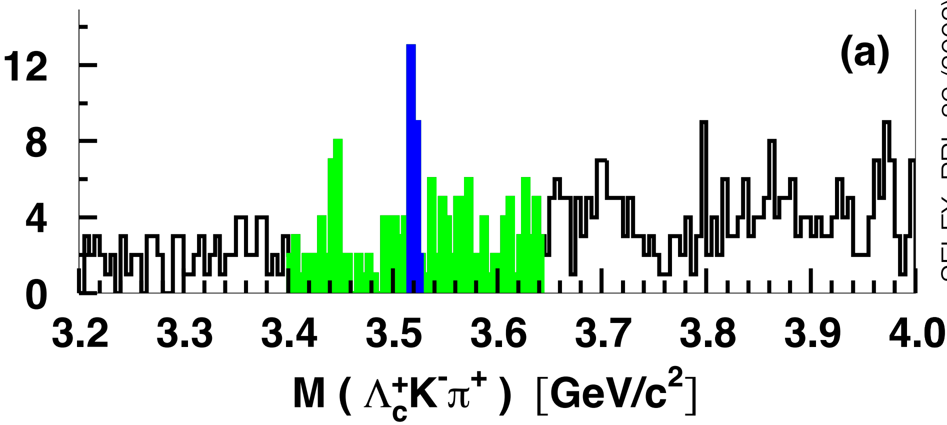
SELEX: PLB 628 (2005) 18-24



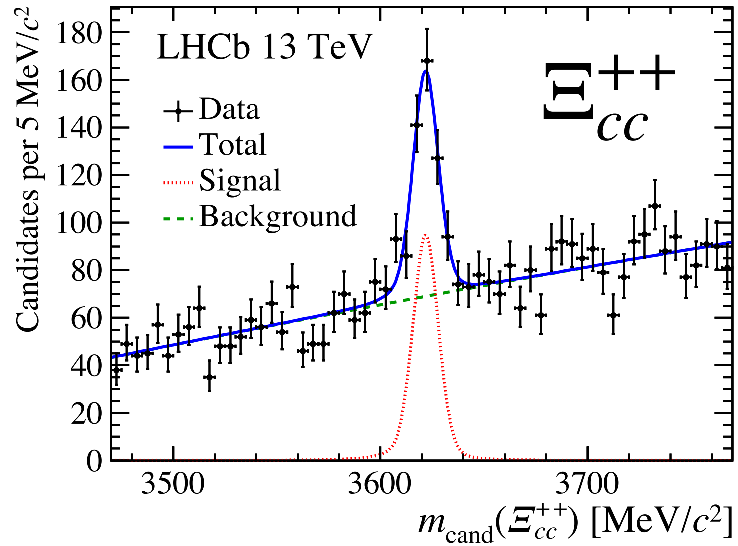
LHCb: PRL 121 (2018) 16, 162002

Ξ_{cc}^{+}?

SELEX 2002

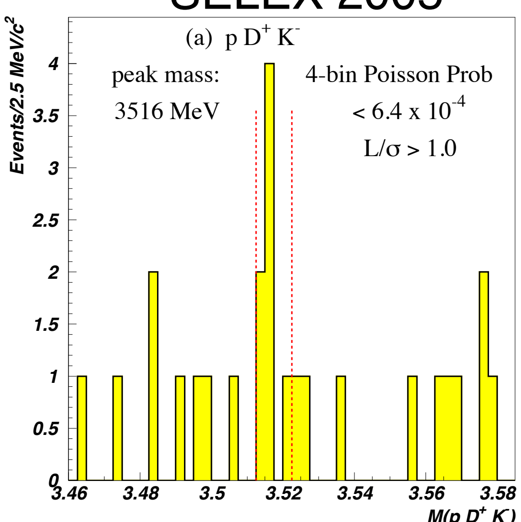


SELEX: PRL 89 (2002) 112001

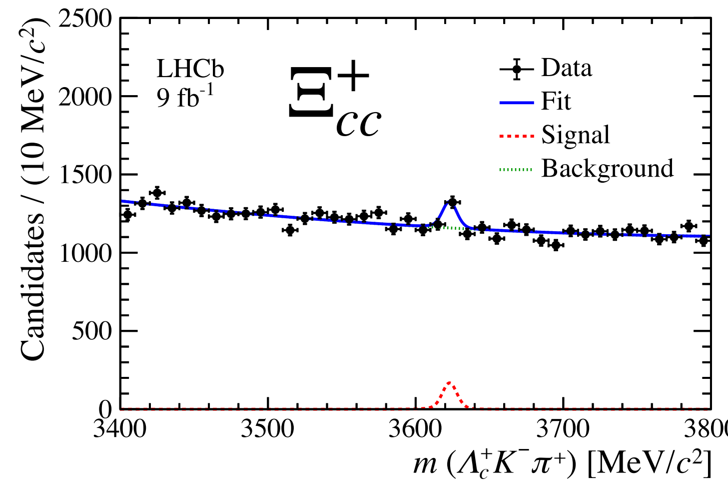


LHCb: PRL 121 (2018) 16, 162002

SELEX 2005



SELEX: PLB 628 (2005) 18-24

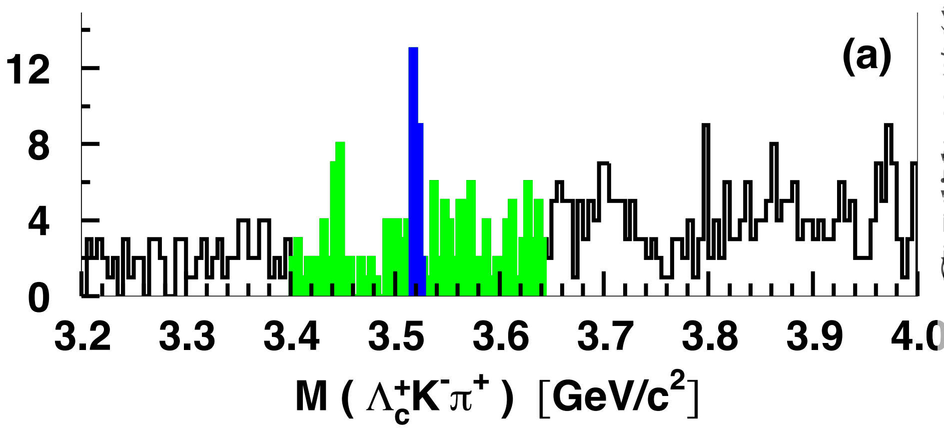


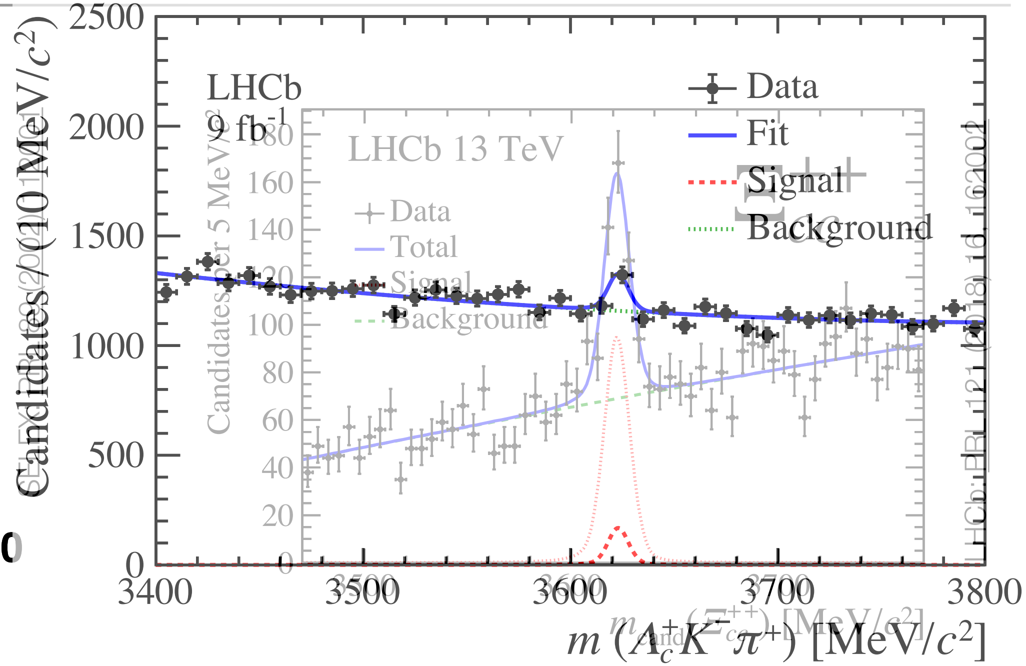
LHCB-PAPER-2021-019-001

1st shown at this conference, by Dana Seman Bobulska

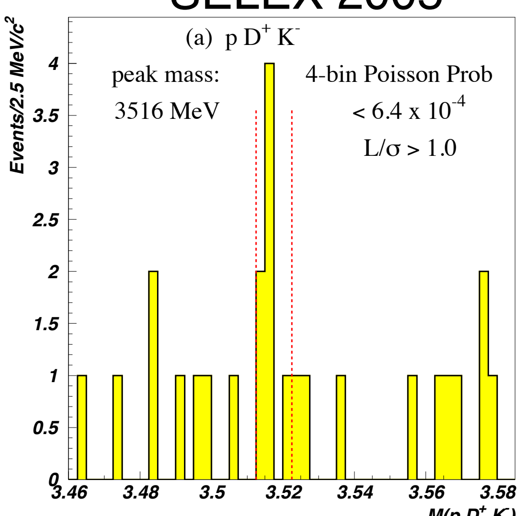
Ξ_{cc}^{+}?

SELEX 2002

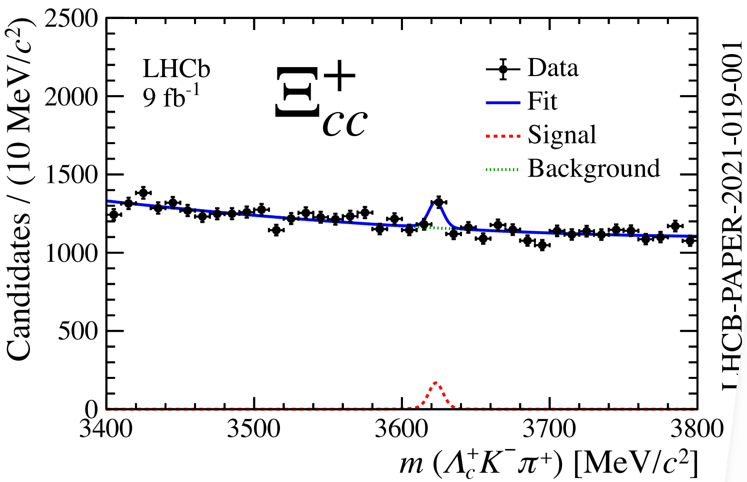




SELEX 2005



SELEX: PLB 628 (2005) 18-24



1st shown at this conference, by Dana Seman Bobulska

Pentaquarks 2006

PENTAQUARK UPDATE

Written February 2006 by G. Trilling (LBNL).

To summarize, with the exception described in the previous paragraph, there has not been a high-statistics confirmation of any of the original experiments that claimed to see the Θ^+; there have been two high-statistics repeats from Jefferson Lab that have clearly shown the original positive claims in those two cases to be wrong; there have been a number of other high-statistics experiments, none of which have found any evidence for the Θ^+; and all attempts to confirm the two other claimed pentaquark states have led to negative results. The conclusion that pentaquarks in general, and the Θ^+, in particular, do not exist, appears compelling.

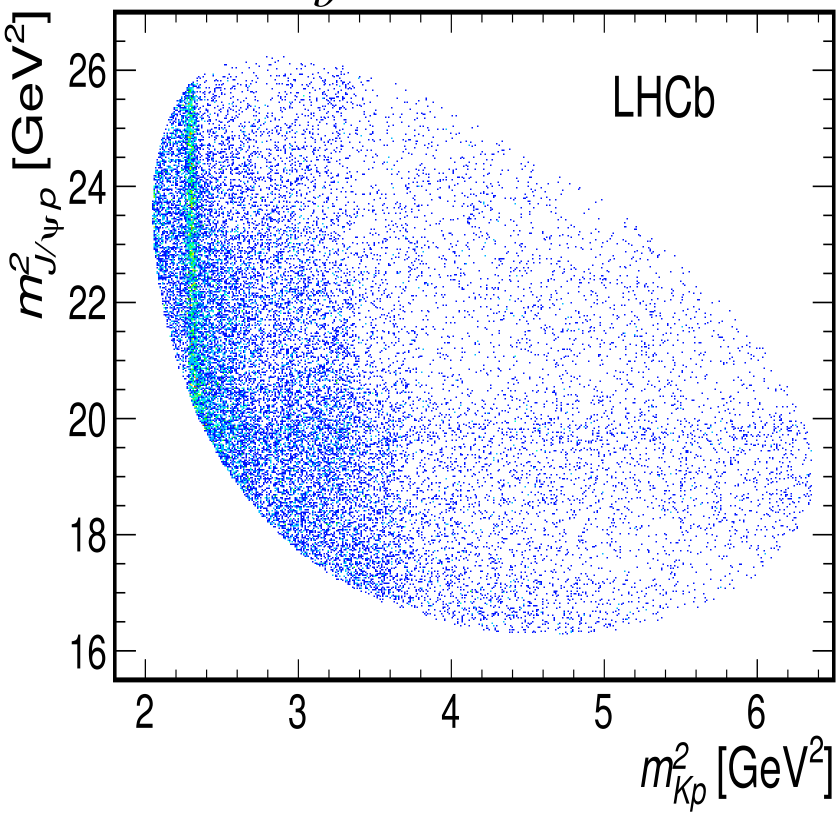
Pentaquarks 2018

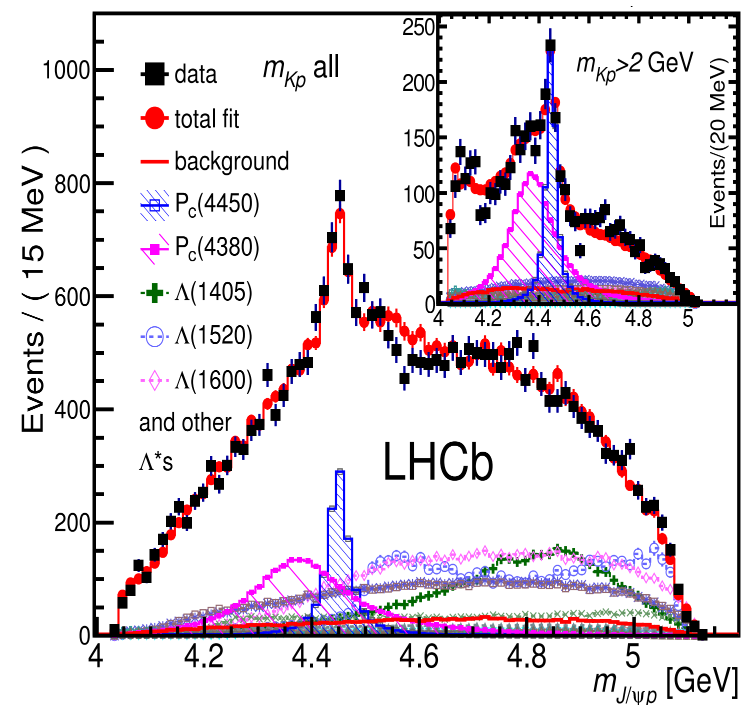
105. Pentaquarks

Written March 2016 by M. Karliner (Tel Aviv U.), T. Skwarnicki (Syracuse U.)

$\Lambda_b^0 \to J/\psi K^- p$

LHCb: PRL 115 (2015) 072001





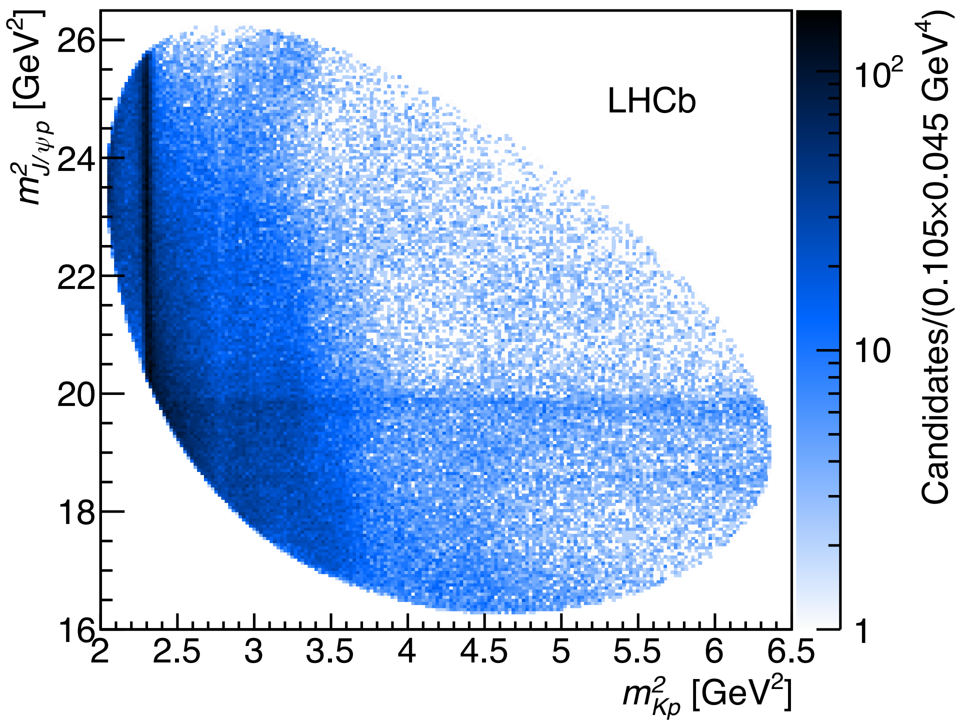
Pentaquarks 2020

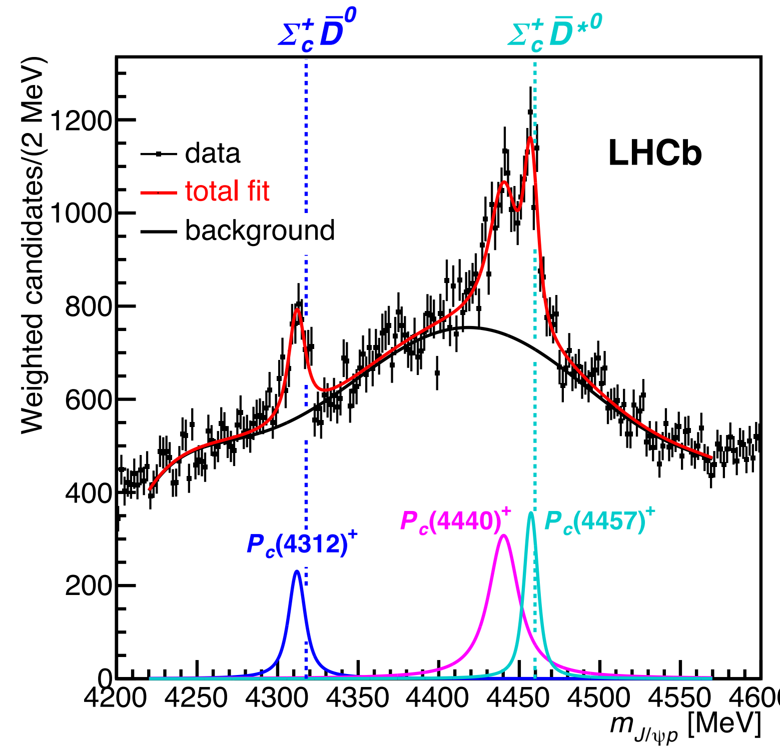
85. Pentaquarks

Revised September 2019 by M. Karliner (Tel Aviv U.) and T. Skwarnicki (Syracuse U.).

$$\Lambda_b^0 \to J/\psi K^- p$$

LHCb: PRL 122 (2019) 22, 222001

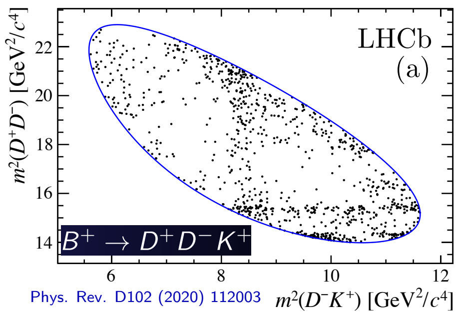


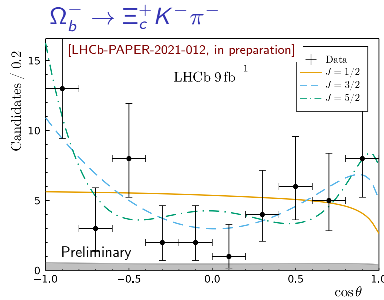


9×stats

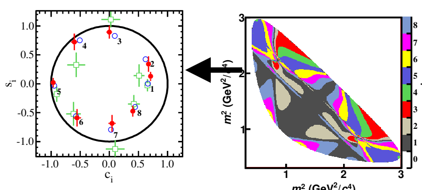
State	M [MeV]	Γ [MeV] (95% CL)	$\mathcal{R}$ [%]
$P_c(4312)^+$	$4311.9 \pm 0.7^{+6.8}_{-0.6}$	$9.8 \pm 2.7^{+\ 3.7}_{-\ 4.5}$ (< 27)	$0.30 \pm 0.07^{+0.34}_{-0.09}$
$P_c(4440)^+$	$4440.3 \pm 1.3^{+4.1}_{-4.7}$	$20.6 \pm 4.9^{+\ 8.7}_{-10.1}$ (< 49)	$1.11 \pm 0.33^{+0.22}_{-0.10}$
$P_c(4457)^+$	$4457.3 \pm 0.6^{+4.1}_{-1.7}$	$6.4 \pm 2.0^{+\ 5.7}_{-\ 1.9}$ (< 20)	$0.53 \pm 0.16^{+0.15}_{-0.13}$

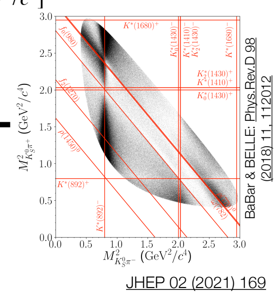
Amplitude Analyses with charm

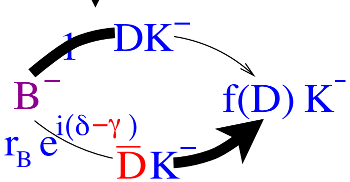


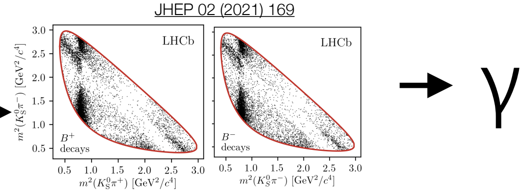


$B \to$ **charm** for charm spectroscopy; discovery and J^{PC}.

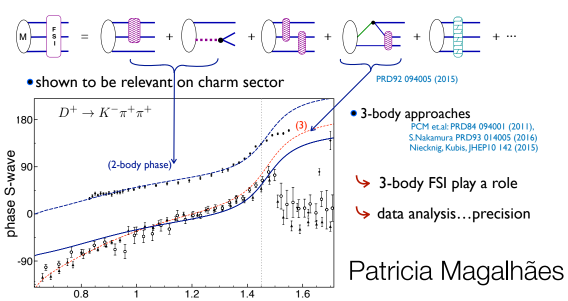


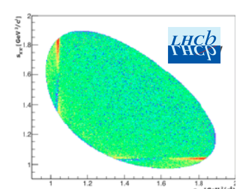






Input to CPV in $B \to$ **charm** and CPV + mixing in charm itself.
(note that even model-independent methods rely on models - the better the model, the higher the statistical precision).



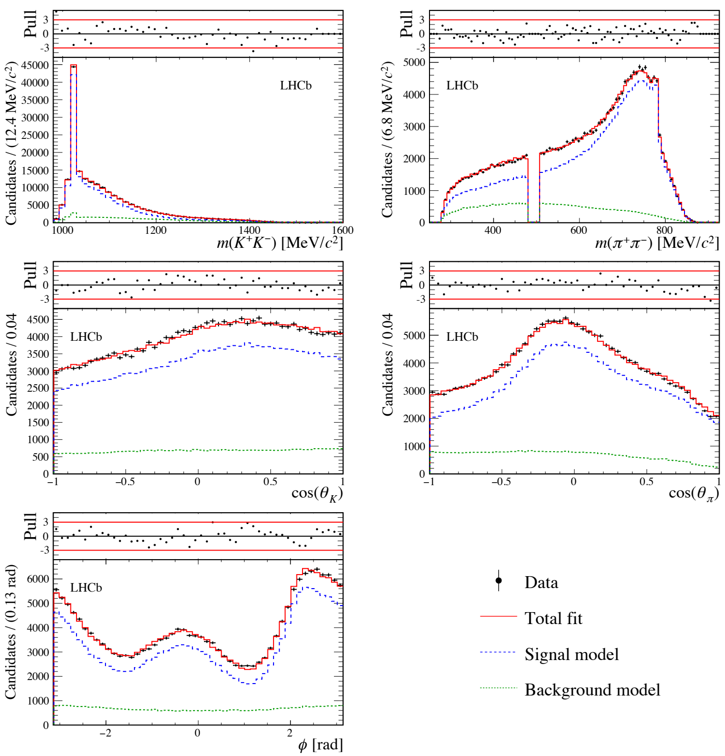


To study strong dynamics and improve amplitude models

Increasingly sophisticated models beyond the isobar being developed and used on data (see e.g. Patricia Magalhães' talk)

$D^0 \to K^+K^-\pi^+\pi^-$ Amplitude Analysis

LHCb: JHEP 02 (2019) 126



$$F_i = \frac{\int |A_i(p)|^2 dp}{\int \left| \sum_j A_j(p) \right|^2 dp}$$

Amplitude	$\lvert c_k \rvert$	$\arg(c_k)$ [rad]	Fit fraction [%]
$D^0 \to [\phi(1020)(\rho-\omega)^0]_{L=0}$	1 (fixed)	0 (fixed)	$23.82 \pm 0.38 \pm 0.50$
$D^0 \to K_1(1400)^+K^-$	$0.614 \pm 0.011 \pm 0.031$	$1.05 \pm 0.02 \pm 0.05$	$19.08 \pm 0.60 \pm 1.46$
$D^0 \to [K^-\pi^+]_{L=0}[K^+\pi^-]_{L=0}$	$0.282 \pm 0.004 \pm 0.008$	$-0.60 \pm 0.02 \pm 0.10$	$18.46 \pm 0.35 \pm 0.94$
$D^0 \to K_1(1270)^+K^-$	$0.452 \pm 0.011 \pm 0.017$	$2.02 \pm 0.03 \pm 0.05$	$18.05 \pm 0.52 \pm 0.98$
$D^0 \to [K^*(892)^0\overline{K}^*(892)^0]_{L=0}$	$0.259 \pm 0.004 \pm 0.018$	$-0.27 \pm 0.02 \pm 0.03$	$9.18 \pm 0.21 \pm 0.28$
$D^0 \to K^*(1680)^0[K^-\pi^+]_{L=0}$	$2.359 \pm 0.036 \pm 0.624$	$0.44 \pm 0.02 \pm 0.03$	$6.61 \pm 0.15 \pm 0.37$
$D^0 \to [K^*(892)^0\overline{K}^*(892)^0]_{L=1}$	$0.249 \pm 0.005 \pm 0.017$	$1.22 \pm 0.02 \pm 0.03$	$4.90 \pm 0.16 \pm 0.18$
$D^0 \to K_1(1270)^-K^+$	$0.220 \pm 0.006 \pm 0.011$	$2.09 \pm 0.03 \pm 0.07$	$4.29 \pm 0.18 \pm 0.41$
$D^0 \to [K^+K^-]_{L=0}[\pi^+\pi^-]_{L=0}$	$0.120 \pm 0.003 \pm 0.018$	$-2.49 \pm 0.03 \pm 0.16$	$3.14 \pm 0.17 \pm 0.72$
$D^0 \to K_1(1400)^-K^+$	$0.236 \pm 0.008 \pm 0.018$	$0.04 \pm 0.04 \pm 0.09$	$2.82 \pm 0.19 \pm 0.39$
$D^0 \to [K^*(1680)^0\overline{K}^*(892)^0]_{L=0}$	$0.823 \pm 0.023 \pm 0.218$	$2.99 \pm 0.03 \pm 0.05$	$2.75 \pm 0.15 \pm 0.19$
$D^0 \to [\overline{K}^*(1680)^0K^*(892)^0]_{L=1}$	$1.009 \pm 0.022 \pm 0.276$	$-2.76 \pm 0.02 \pm 0.03$	$2.70 \pm 0.11 \pm 0.09$
$D^0 \to \overline{K}^*(1680)^0[K^+\pi^-]_{L=0}$	$1.379 \pm 0.029 \pm 0.373$	$1.06 \pm 0.02 \pm 0.03$	$2.41 \pm 0.09 \pm 0.27$
$D^0 \to [\phi(1020)(\rho-\omega)^0]_{L=2}$	$1.311 \pm 0.031 \pm 0.018$	$0.54 \pm 0.02 \pm 0.02$	$2.29 \pm 0.08 \pm 0.08$
$D^0 \to [K^*(892)^0\overline{K}^*(892)^0]_{L=2}$	$0.652 \pm 0.018 \pm 0.043$	$2.85 \pm 0.03 \pm 0.04$	$1.85 \pm 0.09 \pm 0.10$
$D^0 \to \phi(1020)[\pi^+\pi^-]_{L=0}$	$0.049 \pm 0.001 \pm 0.004$	$-1.71 \pm 0.04 \pm 0.37$	$1.49 \pm 0.09 \pm 0.33$
$D^0 \to [K^*(1680)^0\overline{K}^*(892)^0]_{L=1}$	$0.747 \pm 0.021 \pm 0.203$	$0.14 \pm 0.03 \pm 0.04$	$1.48 \pm 0.08 \pm 0.10$
$D^0 \to [\phi(1020)\rho(1450)^0]_{L=1}$	$0.762 \pm 0.035 \pm 0.068$	$1.17 \pm 0.04 \pm 0.04$	$0.98 \pm 0.09 \pm 0.05$
$D^0 \to a_0(980)^0 f_2(1270)^0$	$1.524 \pm 0.058 \pm 0.189$	$0.21 \pm 0.04 \pm 0.19$	$0.70 \pm 0.05 \pm 0.08$
$D^0 \to a_1(1260)^+\pi^-$	$0.189 \pm 0.011 \pm 0.042$	$-2.84 \pm 0.07 \pm 0.38$	$0.46 \pm 0.05 \pm 0.22$
$D^0 \to a_1(1260)^-\pi^+$	$0.188 \pm 0.014 \pm 0.031$	$0.18 \pm 0.06 \pm 0.43$	$0.45 \pm 0.06 \pm 0.16$
$D^0 \to [\phi(1020)(\rho-\omega)^0]_{L=1}$	$0.160 \pm 0.011 \pm 0.005$	$0.28 \pm 0.07 \pm 0.03$	$0.43 \pm 0.05 \pm 0.03$
$D^0 \to [K^*(1680)^0\overline{K}^*(892)^0]_{L=2}$	$1.218 \pm 0.089 \pm 0.354$	$-2.44 \pm 0.08 \pm 0.15$	$0.33 \pm 0.05 \pm 0.06$
$D^0 \to [K^+K^-]_{L=0}(\rho-\omega)^0$	$0.195 \pm 0.015 \pm 0.035$	$2.95 \pm 0.08 \pm 0.29$	$0.27 \pm 0.04 \pm 0.05$
$D^0 \to [\phi(1020)f_2(1270)^0]_{L=1}$	$1.388 \pm 0.095 \pm 0.257$	$1.71 \pm 0.06 \pm 0.37$	$0.18 \pm 0.02 \pm 0.07$
$D^0 \to [K^*(892)^0\overline{K}_2^*(1430)^0]_{L=1}$	$1.530 \pm 0.086 \pm 0.131$	$2.01 \pm 0.07 \pm 0.09$	$0.18 \pm 0.02 \pm 0.02$
		Sum of fit fractions	$129.32 \pm 1.09 \pm 2.38$
		χ^2/ndf	$9242/8121 = 1.14$

$D^0 \to K^+K^-\pi^+\pi^-$ Amplitude Analysis

LHCb: JHEP 02 (2019) 126

Amplitude	Fit fraction [%]
$D^0 \to [\phi(1020)(\rho-\omega)^0]_{L=0}$	$23.82 \pm 0.38 \pm 0.50$
$D^0 \to K_1(1400)^+K^-$	$19.08 \pm 0.60 \pm 1.46$
$D^0 \to [K^-\pi^+]_{L=0}[K^+\pi^-]_{L=0}$	$18.46 \pm 0.35 \pm 0.94$
$D^0 \to K_1(1270)^+K^-$	$18.05 \pm 0.52 \pm 0.98$
$D^0 \to [K^*(892)^0\overline{K}^*(892)^0]_{L=0}$	$9.18 \pm 0.21 \pm 0.28$
$D^0 \to K^*(1680)^0[K^-\pi^+]_{L=0}$	$6.61 \pm 0.15 \pm 0.37$
$D^0 \to [K^*(892)^0\overline{K}^*(892)^0]_{L=1}$	$4.90 \pm 0.16 \pm 0.18$
$D^0 \to K_1(1270)^-K^+$	$4.29 \pm 0.18 \pm 0.41$
$D^0 \to [K^+K^-]_{L=0}[\pi^+\pi^-]_{L=0}$	$3.14 \pm 0.17 \pm 0.72$
$D^0 \to K_1(1400)^-K^+$	$2.82 \pm 0.19 \pm 0.39$
$D^0 \to [K^*(1680)^0\overline{K}^*(892)^0]_{L=0}$	$2.75 \pm 0.15 \pm 0.19$
$D^0 \to [\overline{K}^*(1680)^0K^*(892)^0]_{L=1}$	$2.70 \pm 0.11 \pm 0.09$
$D^0 \to \overline{K}^*(1680)^0[K^+\pi^-]_{L=0}$	$2.41 \pm 0.09 \pm 0.27$
$D^0 \to [\phi(1020)(\rho-\omega)^0]_{L=2}$	$2.29 \pm 0.08 \pm 0.08$
$D^0 \to [K^*(892)^0\overline{K}^*(892)^0]_{L=2}$	$1.85 \pm 0.09 \pm 0.10$
$D^0 \to \phi(1020)[\pi^+\pi^-]_{L=0}$	$1.49 \pm 0.09 \pm 0.33$
$D^0 \to [K^*(1680)^0\overline{K}^*(892)^0]_{L=1}$	$1.48 \pm 0.08 \pm 0.10$
$D^0 \to [\phi(1020)\rho(1450)^0]_{L=1}$	$0.98 \pm 0.09 \pm 0.05$
$D^0 \to a_0(980)^0f_2(1270)^0$	$0.70 \pm 0.05 \pm 0.08$
$D^0 \to a_1(1260)^+\pi^-$	$0.46 \pm 0.05 \pm 0.22$
$D^0 \to a_1(1260)^-\pi^+$	$0.45 \pm 0.06 \pm 0.16$
$D^0 \to [\phi(1020)(\rho-\omega)^0]_{L=1}$	$0.43 \pm 0.05 \pm 0.03$
$D^0 \to [K^*(1680)^0\overline{K}^*(892)^0]_{L=2}$	$0.33 \pm 0.05 \pm 0.06$
$D^0 \to [K^+K^-]_{L=0}(\rho-\omega)^0$	$0.27 \pm 0.04 \pm 0.05$
$D^0 \to [\phi(1020)f_2(1270)^0]_{L=1}$	$0.18 \pm 0.02 \pm 0.07$
$D^0 \to [K^*(892)^0\overline{K}_2^*(1430)^0]_{L=1}$	$0.18 \pm 0.02 \pm 0.02$
	$129.32 \pm 1.09 \pm 2.38$
	$9242/8121 = 1.14$

Amplitude	Fit fraction [%]
$D^0 \to [\phi(1020)(\rho-\omega)^0]_{L=0}$	24.12 ± 0.40
$D^0 \to K_1(1400)^+K^-$	19.34 ± 0.47
$D^0 \to K_1(1270)^+K^-$	19.28 ± 0.39
$D^0 \to [K^-\pi^+]_{L=0}[K^+\pi^-]_{L=0}$	19.20 ± 0.36
$D^0 \to [K^*(892)^0\overline{K}^*(892)^0]_{L=0}$	9.36 ± 0.21
$D^0 \to K^*(1680)^0[K^-\pi^+]_{L=0}$	6.22 ± 0.15
$D^0 \to [K^*(892)^0\overline{K}^*(892)^0]_{L=1}$	4.81 ± 0.16
$D^0 \to K_1(1270)^-K^+$	4.45 ± 0.18
$D^0 \to [K^+K^-]_{L=0}[\pi^+\pi^-]_{L=0}$	4.18 ± 0.21
$D^0 \to K_1(1400)^-K^+$	2.94 ± 0.19
$D^0 \to [K^*(1680)^0\overline{K}^*(892)^0]_{L=0}$	2.79 ± 0.15
$D^0 \to [\overline{K}^*(1680)^0K^*(892)^0]_{L=1}$	2.64 ± 0.11
$D^0 \to \overline{K}^*(1680)^0[K^+\pi^-]_{L=0}$	2.44 ± 0.09
$D^0 \to [\phi(1020)(\rho-\omega)^0]_{L=2}$	2.25 ± 0.08
$D^0 \to [K^*(892)^0\overline{K}^*(892)^0]_{L=2}$	1.73 ± 0.09
$D^0 \to \phi(1020)[\pi^+\pi^-]_{L=0}$	1.43 ± 0.09
$D^0 \to [K^*(1680)^0\overline{K}^*(892)^0]_{L=1}$	1.30 ± 0.08
$D^0 \to [\phi(1020)\rho(1450)^0]_{L=1}$	0.98 ± 0.09
$D^0 \to a_0(980)^0f_2(1270)^0$	0.70 ± 0.05
$D^0 \to a_1(1260)^+\pi^-$	0.50 ± 0.06
$D^0 \to a_1(1260)^-\pi^+$	0.45 ± 0.06
$D^0 \to [K^*(1680)^0\overline{K}^*(892)^0]_{L=2}$	0.45 ± 0.06
$D^0 \to [\phi(1020)(\rho-\omega)^0]_{L=1}$	0.44 ± 0.05
$D^0 \to [K^+K^-]_{L=0}(\rho-\omega)^0$	0.30 ± 0.04
$D^0 \to [\phi(1020)f_2(1270)^0]_{L=1}$	0.19 ± 0.03
$D^0 \to [K^*(892)^0\overline{K}_2^*(1430)^0]_{L=1}$	0.15 ± 0.02
$D^0 \to [K_2^*(1430)^0\overline{K}_2^*(1430)^0]_{L=0}$	0.11 ± 0.02
$D^0 \to [f_2(1270)^0f_2(1270)^0]_{L=0}$	0.08 ± 0.02
$D^0 \to [\overline{K}^*(892)^0K_2^*(1430)^0]_{L=2}$	0.05 ± 0.01
$D^0 \to [\phi(1020)f_2(1270)^0]_{L=2}$	0.04 ± 0.01
	132.92 ± 0.98
	$9092/8113 = 1.12$

How to enter amplitude analysis results in the PDG?

Currently, we enter fit-fractions as branching ratios.

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Don’t do that. Ever.
Individual amplitudes and thus fit-fractions are meaningful only in the context of the amplitude model.

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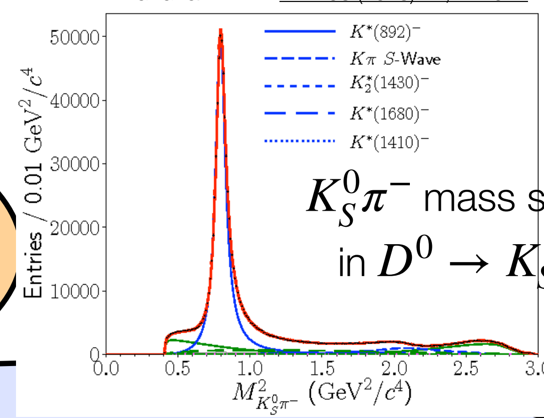
BaBar & BELLE: PRD 98 (2018) 11, 112012



$K_S^0\pi^-$ mass spectrum in $D^0 \to K_S\pi^+\pi^-$

Do you really want to remove $D^0 \to K^{*-}\pi^+$ from the listings?

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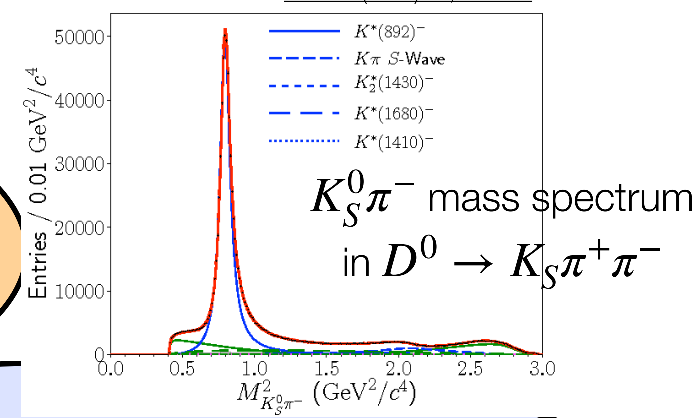
BaBar & BELLE: PRD 98 (2018) 11, 112012



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Do you really want to remove $D^0 \to K^{*-}\pi^+$ from the listings?

Maybe only include large narrow resonance-structures?

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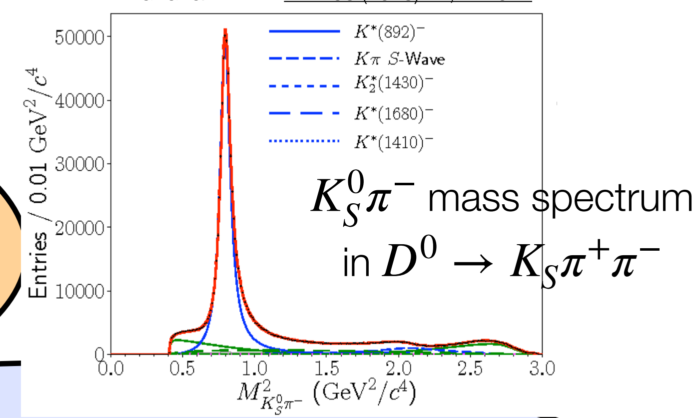


Don't do that. Ever.
Individual amplitudes and thus fit-fractions are meaningful only in the context of the amplitude model.

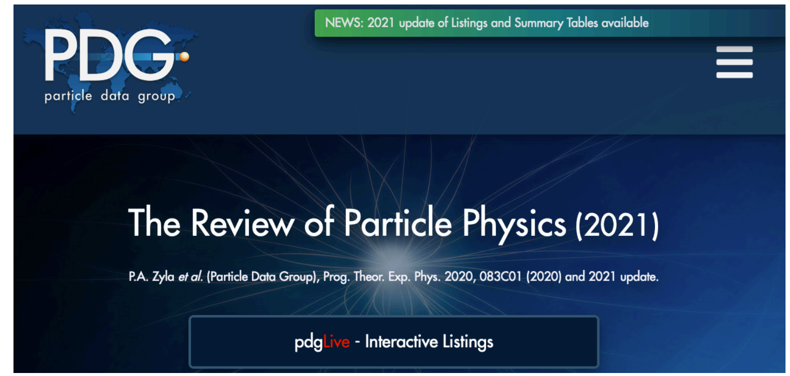
Do you really want to remove $D^0 \to K^{*-}\pi^+$ from the listings?

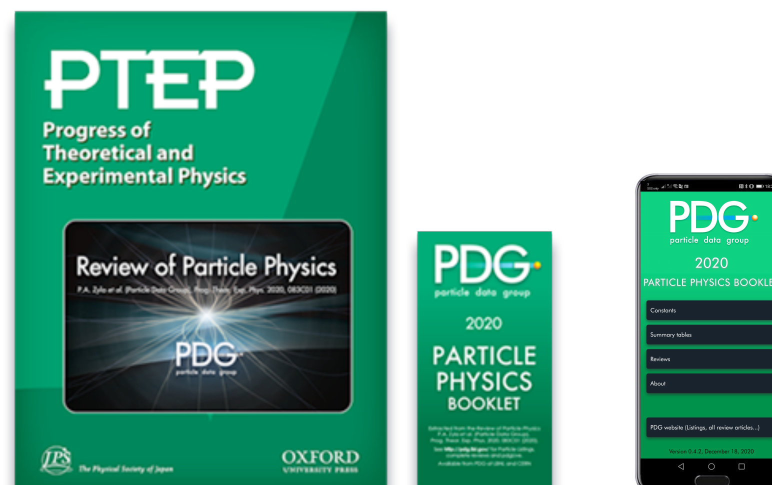
Maybe only include large narrow resonance-structures?

Where's the cut-off? And in terms of what?
$M/\Gamma \times \mathbf{significance}$?
And what about non-resonant contributions?

Summary

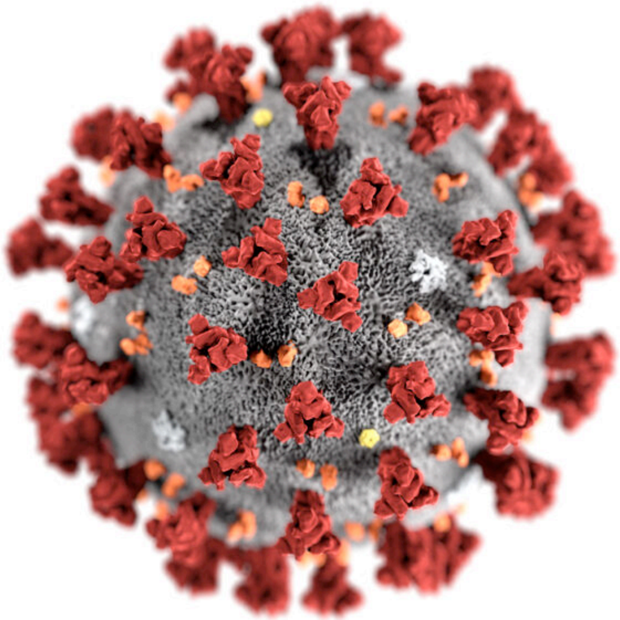
- Charm is an amazingly active field. A huge number of new results keeps the PDG authors on their toes.
- Charm is full of surprises.
- Only had time to show a small subset of results since CHARM 2018:
  - We found CP violation in charm!!
  - Lots of new particles.
  - Charm for precision B physics
  - How should we encode amplitude analyses? We welcome suggestions: (Jonas.Rademacker@bristol.ac.uk)

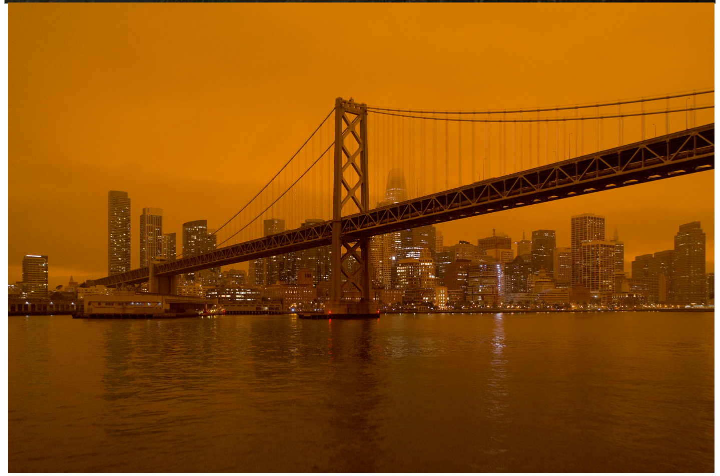




Backup slides

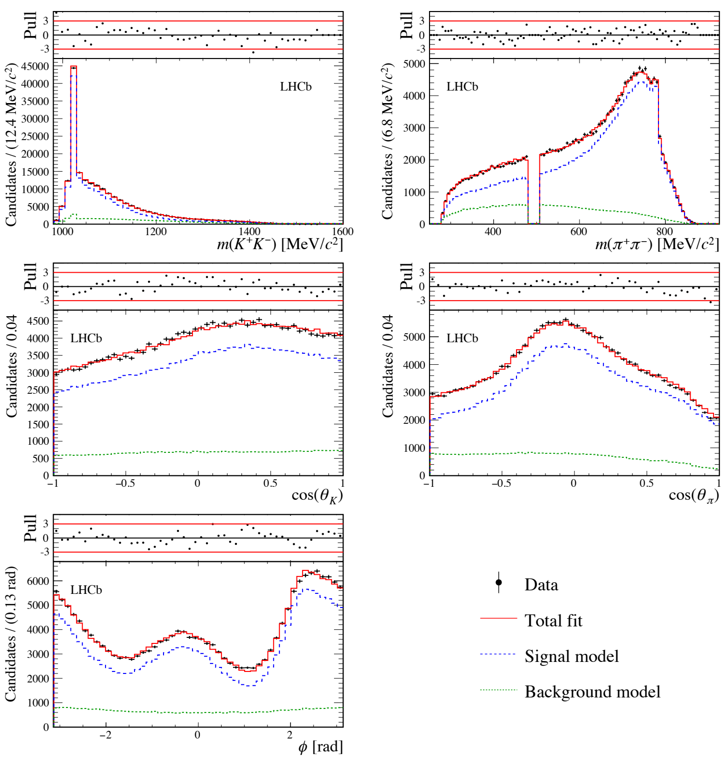
Bad things



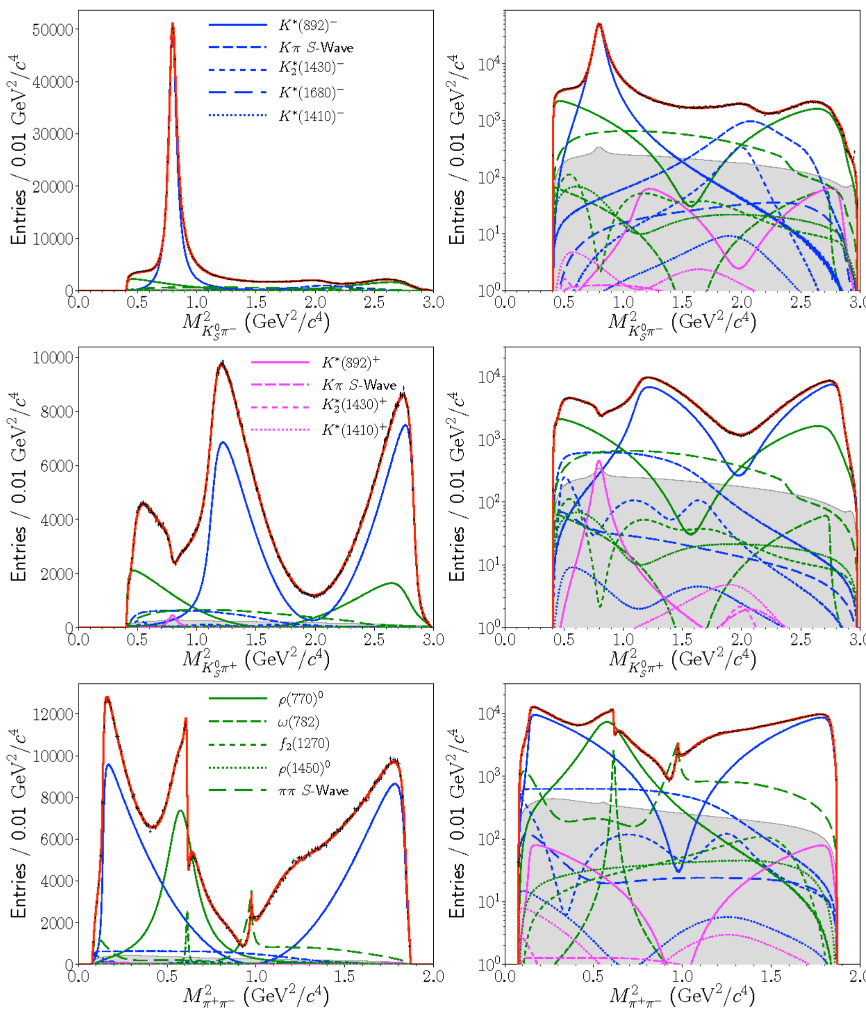


D2 KK pi pi

LHCb: JHEP 02 (2019) 126



Amplitude	$A_{\lvert c_k\rvert}$ [%]	$\Delta\arg(c_k)$ [%]	$A_{\mathcal{F}_k}$ [%]
$D^0 \to [\phi(1020)(\rho-\omega)^0]_{L=0}$	0 (fixed)	0 (fixed)	$-1.8\pm1.5\pm0.2$
$D^0 \to K_1(1400)^+K^-$	$-1.4\pm1.1\pm0.2$	$1.3\pm1.5\pm0.3$	$-4.5\pm2.1\pm0.3$
$D^0 \to [K^-\pi^+]_{L=0}[K^+\pi^-]_{L=0}$	$1.9\pm1.1\pm0.3$	$-1.2\pm1.3\pm0.3$	$2.0\pm1.8\pm0.7$
$D^0 \to K_1(1270)^+K^-$	$-0.4\pm1.0\pm0.2$	$-1.1\pm1.4\pm0.2$	$-2.6\pm1.7\pm0.2$
$D^0 \to [K^*(892)^0\overline{K}^*(892)^0]_{L=0}$	$-1.3\pm1.3\pm0.3$	$-1.7\pm1.5\pm0.2$	$-4.3\pm2.2\pm0.5$
$D^0 \to K^*(1680)^0[K^-\pi^+]_{L=0}$	$2.2\pm1.3\pm0.3$	$1.4\pm1.5\pm0.2$	$2.6\pm2.2\pm0.4$
$D^0 \to [K^*(892)^0\overline{K}^*(892)^0]_{L=1}$	$-0.4\pm1.7\pm0.2$	$3.7\pm2.0\pm0.2$	$-2.6\pm3.2\pm0.3$
$D^0 \to K_1(1270)^-K^+$	$2.6\pm1.7\pm0.4$	$-0.1\pm2.1\pm0.3$	$3.3\pm3.5\pm0.5$
$D^0 \to [K^+K^-]_{L=0}[\pi^+\pi^-]_{L=0}$	$3.5\pm2.5\pm1.5$	$-5.5\pm2.6\pm1.6$	$5.1\pm5.1\pm3.1$
$D^0 \to K_1(1400)^-K^+$	$0.2\pm2.9\pm0.7$	$2.5\pm3.5\pm1.0$	$-1.3\pm6.0\pm1.0$
$D^0 \to [K^*(1680)^0\overline{K}^*(892)^0]_{L=0}$	$4.0\pm2.7\pm0.8$	$-5.4\pm2.8\pm0.8$	$6.2\pm5.2\pm1.5$
$D^0 \to [\overline{K}^*(1680)^0K^*(892)^0]_{L=1}$	$-0.4\pm2.1\pm0.3$	$0.4\pm2.1\pm0.3$	$-2.5\pm3.9\pm0.4$
$D^0 \to \overline{K}^*(1680)^0[K^+\pi^-]_{L=0}$	$2.1\pm2.0\pm0.6$	$-1.8\pm2.2\pm0.3$	$2.4\pm3.7\pm1.1$
$D^0 \to [\phi(1020)(\rho-\omega)^0]_{L=2}$	$0.8\pm1.9\pm0.3$	$-1.2\pm2.0\pm0.5$	$-0.1\pm3.3\pm0.5$
$D^0 \to [K^*(892)^0\overline{K}^*(892)^0]_{L=2}$	$-0.6\pm2.5\pm0.4$	$0.6\pm2.6\pm0.4$	$-3.0\pm5.0\pm0.7$
$D^0 \to \phi(1020)[\pi^+\pi^-]_{L=0}$	$3.8\pm3.1\pm0.7$	$-0.5\pm3.9\pm0.7$	$5.8\pm6.1\pm0.8$
$D^0 \to [K^*(1680)^0\overline{K}^*(892)^0]_{L=1}$	$1.6\pm2.8\pm0.5$	$0.7\pm3.0\pm0.4$	$1.3\pm5.3\pm0.6$
$D^0 \to [\phi(1020)\rho(1450)^0]_{L=1}$	$4.6\pm4.1\pm0.6$	$9.3\pm3.3\pm0.6$	$7.5\pm8.5\pm1.1$
$D^0 \to a_0(980)^0f_2(1270)^0$	$1.6\pm3.6\pm0.7$	$-7.3\pm3.3\pm0.8$	$1.5\pm7.2\pm1.3$
$D^0 \to a_1(1260)^+\pi^-$	$-4.4\pm5.6\pm3.7$	$9.3\pm6.1\pm1.3$	$-10.6\pm11.7\pm7.0$
$D^0 \to a_1(1260)^-\pi^+$	$-3.4\pm7.0\pm1.9$	$-5.8\pm5.6\pm4.3$	$-8.7\pm13.7\pm2.9$
$D^0 \to [\phi(1020)(\rho-\omega)^0]_{L=1}$	$2.1\pm5.2\pm0.8$	$-12.2\pm5.5\pm0.6$	$2.4\pm11.0\pm1.4$
$D^0 \to [K^*(1680)^0\overline{K}^*(892)^0]_{L=2}$	$5.2\pm7.1\pm1.9$	$-5.6\pm8.1\pm1.3$	$8.5\pm14.3\pm3.5$
$D^0 \to [K^+K^-]_{L=0}(\rho-\omega)^0$	$11.7\pm6.0\pm1.9$	$4.8\pm6.2\pm1.1$	$21.3\pm12.5\pm2.8$
$D^0 \to [\phi(1020)f_2(1270)^0]_{L=1}$	$2.7\pm6.7\pm1.7$	$0.9\pm6.0\pm1.7$	$3.6\pm13.3\pm3.0$
$D^0 \to [K^*(892)^0\overline{K}_2^*(1430)^0]_{L=1}$	$3.9\pm5.2\pm1.0$	$6.8\pm6.4\pm1.4$	$6.1\pm10.8\pm1.8$



BaBar & BELLE: Phys.Rev.D 98 (2018) 11, 112012

D2KKK

LHCb: JHEP 04 (2019) 063

How to encode amplitude analyses

New website


NEWS: 2021 update of Listings and Summary Tables available
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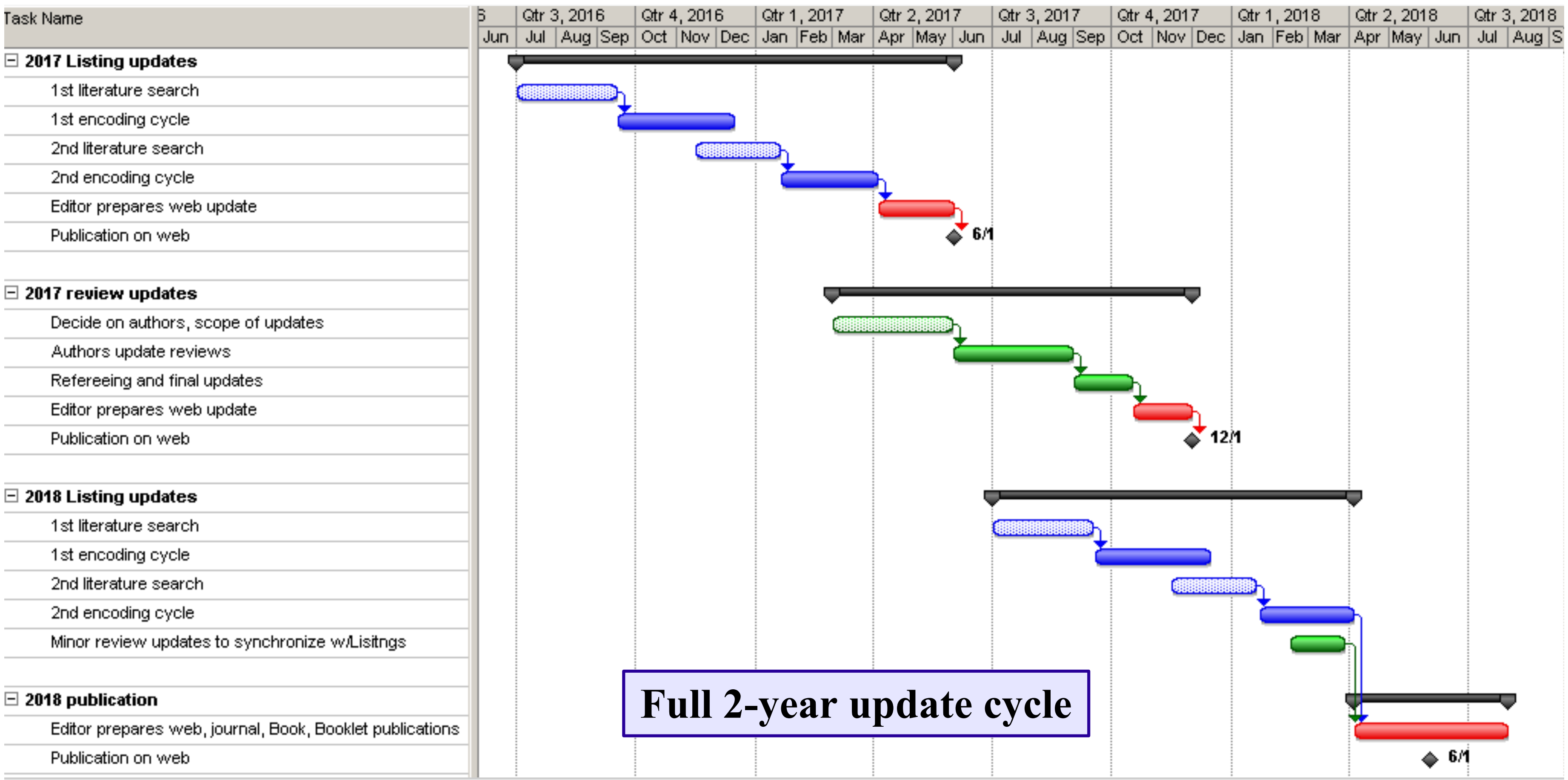
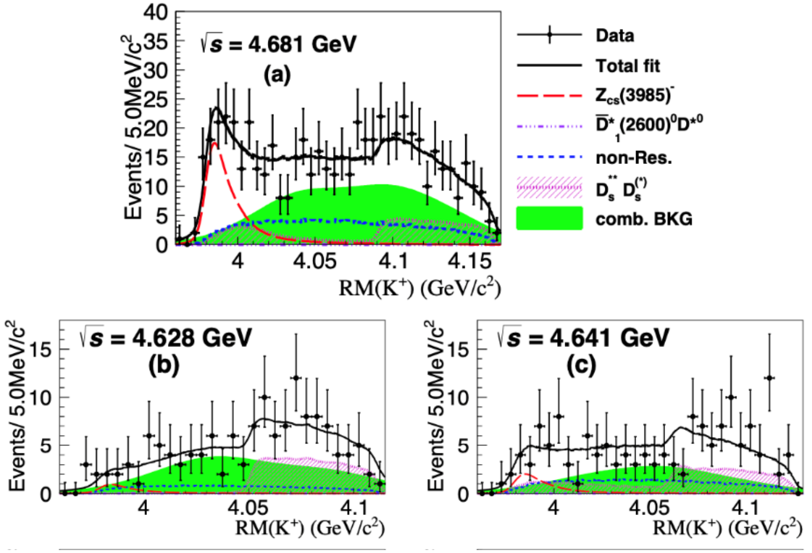
2 year schedule



BESIII results



$$m_{\text{pole}}(Z_{cs}(3985)^-) = (3982.5^{+1.8}_{-2.6} \pm 2.1)\,\text{MeV}/c^2,$$
$$\Gamma_{\text{pole}}(Z_{cs}(3985)^-) = (12.8^{+5.3}_{-4.4} \pm 3.0)\,\text{MeV}.$$

[arXiv:2011.07855]

Taking into account the DD^* threshold: Flatté [PRD102(2020)092005]

Adding external information on branching fractions from Belle and BaBar distorts the lineshape [PRD80(2009)074004].

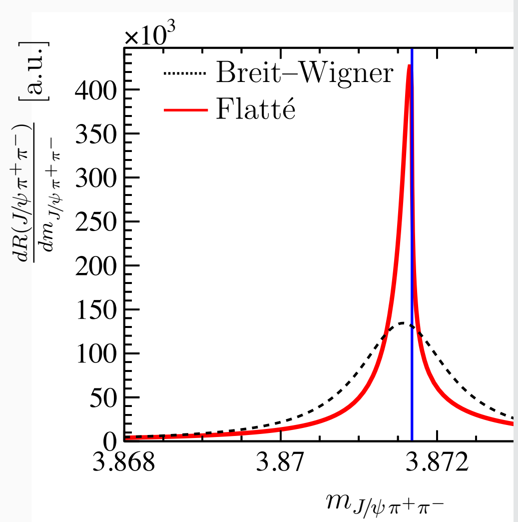
Shape parameters:

Mode [MeV]	Mean [MeV]	FWHM [MeV]
$3871.69^{+0.00+0.05}_{-0.04-0.13}$	$3871.66^{+0.07+0.11}_{-0.06-0.13}$	$0.22^{+0.06+0.25}_{-0.08-0.17}$

Systematic uncertainties of equal importance:

- Resolution+Bkg model
- Momentum scale
- Threshold mass

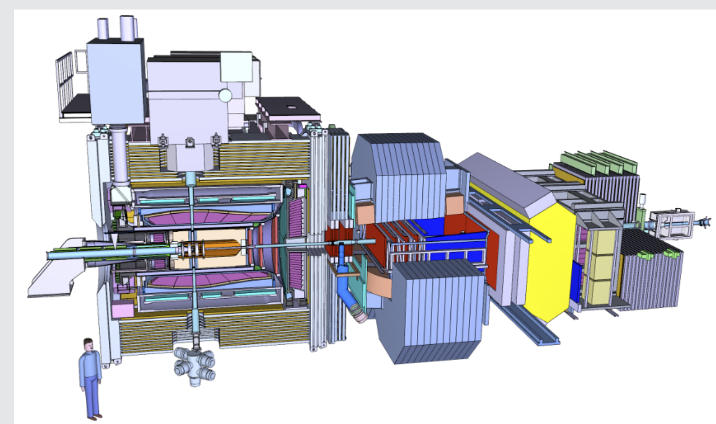
Small effect: D^{0*} width



- $J/\psi\pi\pi$ data alone cannot distinguish line shapes
- Flatté narrower than BW by factor 5

Resolve lineshape

See K. Götzen talk tomorrow



The $\bar{P}$ANDA project at FAIR

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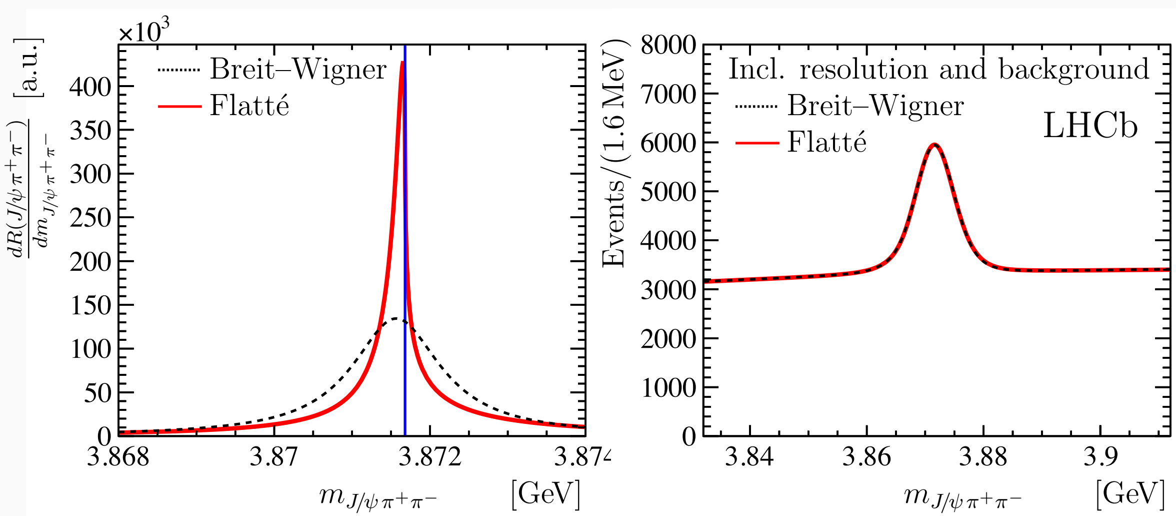
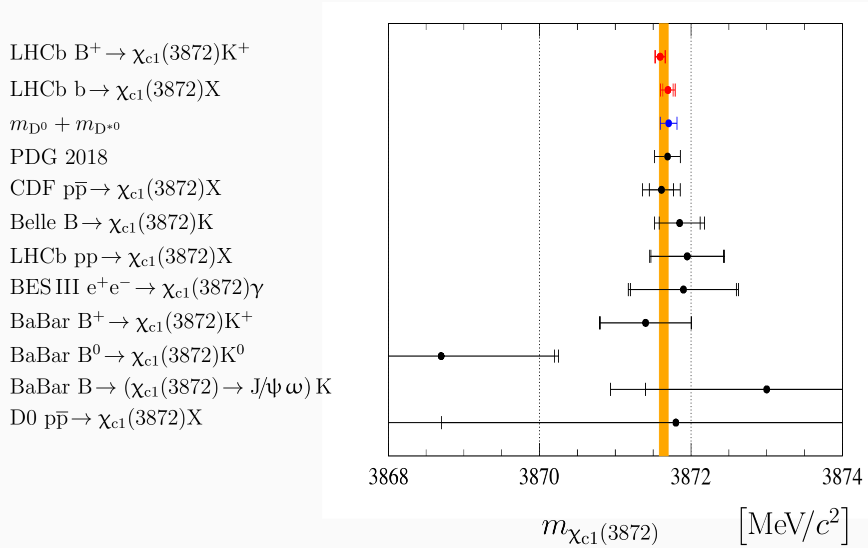
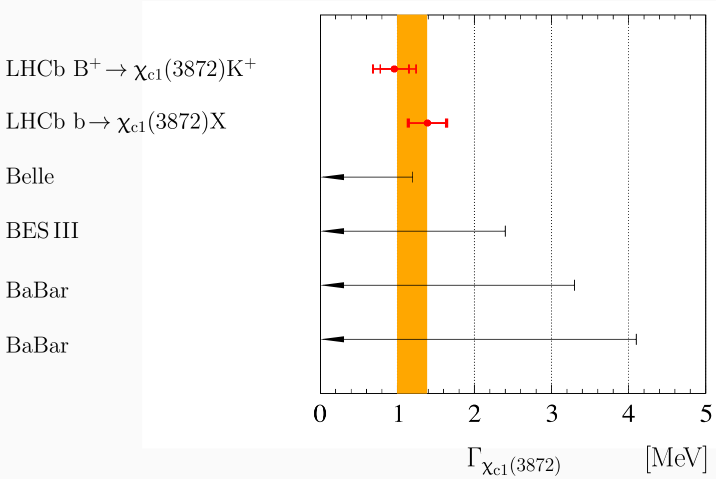


Breit-Wigner parameters [PRD102(2020)092005][JHEP08(2020)123]

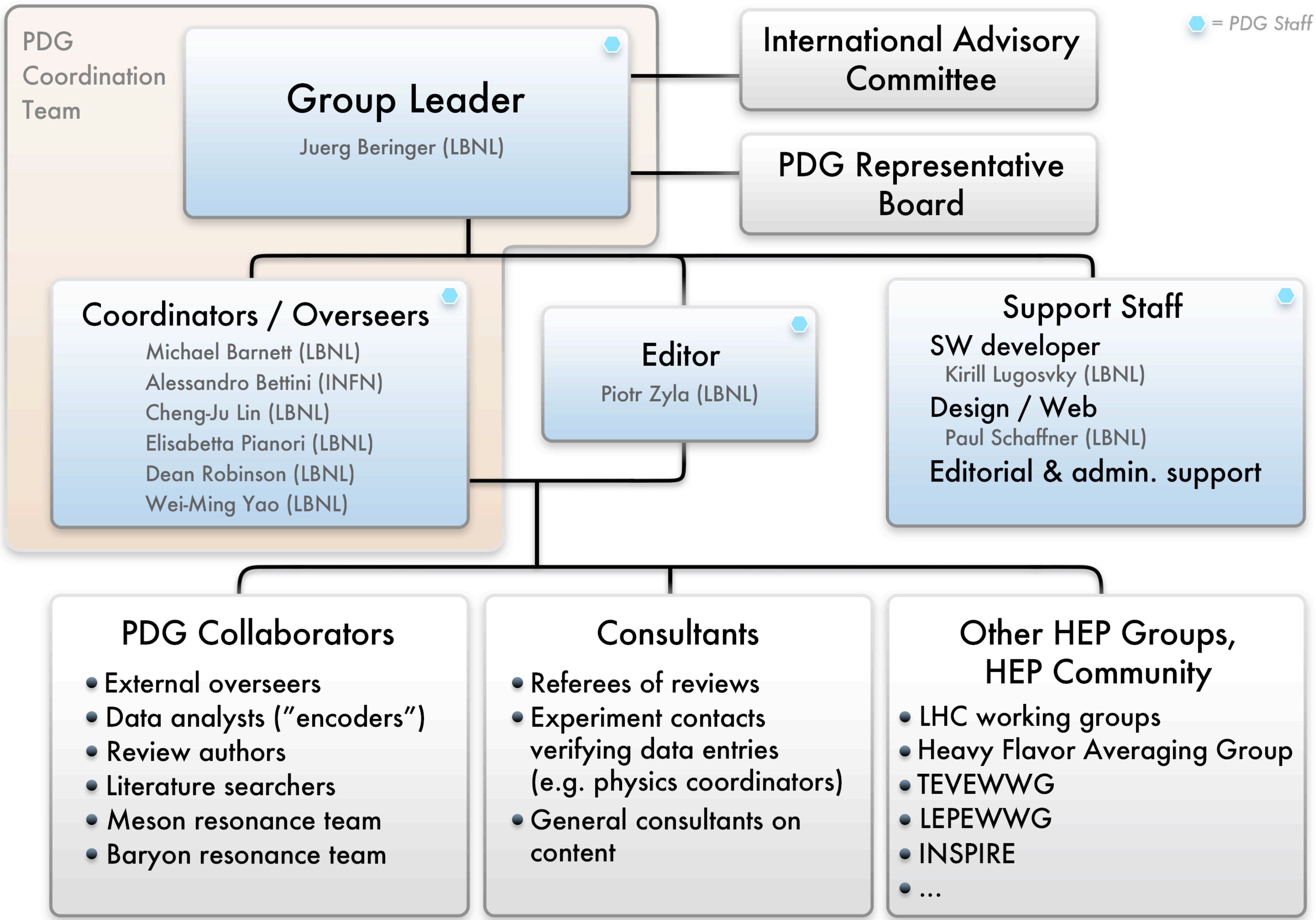
Comparison between inclusive and exclusive analysis and previous measurements





First time a width was established for this state.

4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• Heavy Flavor Averaging Group
• TEVEWWG
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• ...

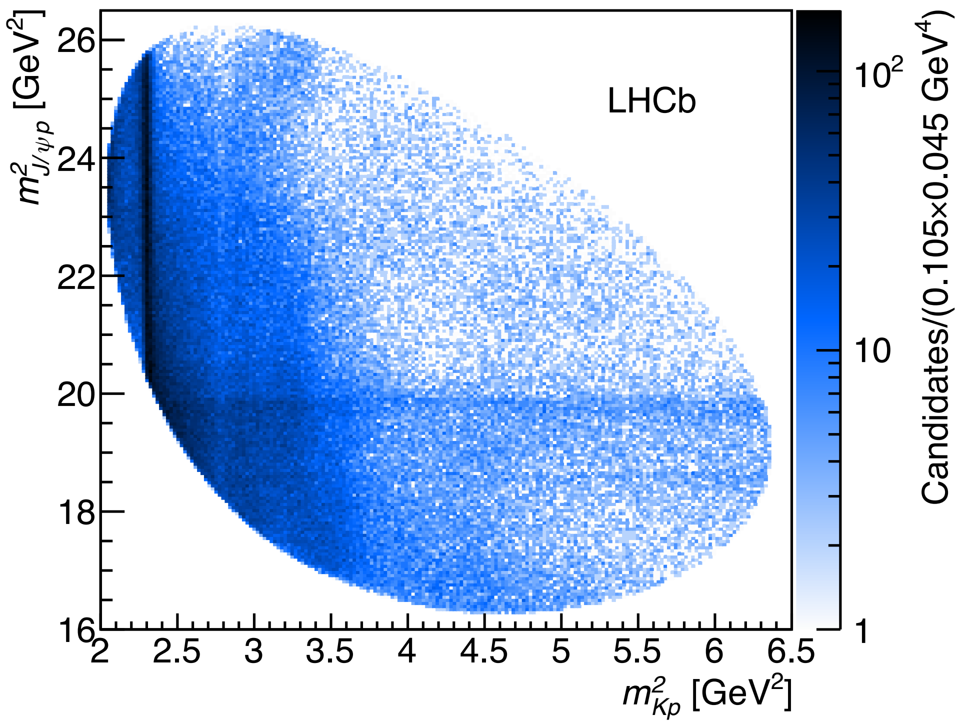
Barkas and Rosenfeld UCRL-8030 Table I

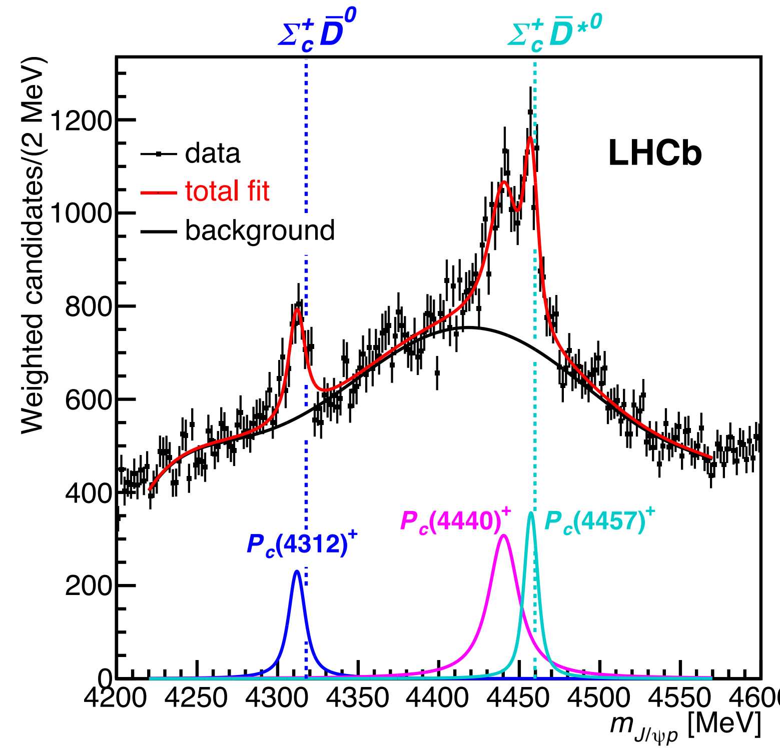
Masses and mean lives of elementary particles; November, 1957
(The antiparticles are assumed to have the same spins, masses, and mean lives as the particles listed)

	Particle	Spin	Mass (Errors represent standard deviation) (Mev)	Mass difference (Mev)	Mean life (sec)	Decay rate (number per second)
Photon	γ	1	0		stable	0
Leptons	ν	$\frac{1}{2}$	0		stable	0
	e^-	$\frac{1}{2}$	0.510976 (a)		stable	0
	μ^-	$\frac{1}{2}$	105.70 $\pm$0.06 (a)		(2.22 $\pm$0.02) $\times 10^{-6}$	0.45 $\times 10^{6}$
Mesons	π^+	0	139.63 $\pm$0.06 (a)	4.6 (a)	(2.56 $\pm$0.05) $\times 10^{-8}$ (a)	0.39 $\times 10^{8}$
	π^0	0	135.04 $\pm$0.16 (a)		<4 $\times 10^{-16}$ (d)	> 2.5 $\times 10^{15}$
	K^+	0	494.0 $\pm$0.2 (g)	0.4$\pm$1.8	(1.224$\pm$0.013) $\times 10^{-8}$ (h)	0.815 $\times 10^{8}$
	K^0	0	494.4 $\pm$1.8 (i)		K_1: (0.95 $\pm$0.08) $\times 10^{-10}$ (e)	1.05 $\times 10^{10}$
					K_2: (4< τ <13) $\times 10^{-8}$ (c)	(0.07< τ <0.25) $\times 10^{8}$
Baryons	p	$\frac{1}{2}$	938.213 $\pm$0.01 (a)		stable	0.0
	n	$\frac{1}{2}$	939.506 $\pm$0.01 (a)		(1.04 $\pm$0.13) $\times 10^{+3}$ (a)	0.96 $\times 10^{-3}$
	Λ	$\frac{1}{2}$	1115.2 $\pm$0.14 (j)		(2.77 $\pm$0.15) $\times 10^{-10}$ (k)	0.36 $\times 10^{10}$
	Σ^+	$\frac{1}{2}$	1189.4 $\pm$0.25 (l)	7.1 $\pm$ 0.4	(0.83 $^{+.06}_{-.05}$) $\times 10^{-10}$ (m)	1.21 $\times 10^{10}$
	Σ^-	$\frac{1}{2}$	1196.5 $\pm$0.5 (n)		(1.67 $\pm$0.17) $\times 10^{-10}$ (o)	0.60 $\times 10^{10}$
	Σ^0	$\frac{1}{2}$	1190.5 $^{+0.9}_{-1.4}$ (p)	6.0 $^{+1.4}_{-0.9}$	(<0.1) $\times 10^{-10}$ (b) theoretically ~10^{-19}	> 10 $\times 10^{10}$ theoretically ~10^{19}
	Ξ^-	?	1320.4 $\pm$ 2.2 (q)		(4.6< τ < 200) $\times 10^{-10}$ (f)	(>0.005, <0.2) $\times 10^{10}$
	Ξ^0	?	?		?	

Masses and mean lifetimes of elementary particles, as shown in Table I of the first wallet card issued in 1957. Image credit: Barkas and Rosenfeld, UCRL-8030.

Pentaquarks 2020





State	M [MeV]	Γ [MeV] (95% CL)	$\mathcal{R}$ [%]
$P_c(4312)^+$	$4311.9 \pm 0.7^{+6.8}_{-0.6}$	$9.8 \pm 2.7^{+\ 3.7}_{-\ 4.5}$ (< 27)	$0.30 \pm 0.07^{+0.34}_{-0.09}$
$P_c(4440)^+$	$4440.3 \pm 1.3^{+4.1}_{-4.7}$	$20.6 \pm 4.9^{+\ 8.7}_{-10.1}$ (< 49)	$1.11 \pm 0.33^{+0.22}_{-0.10}$
$P_c(4457)^+$	$4457.3 \pm 0.6^{+4.1}_{-1.7}$	$6.4 \pm 2.0^{+\ 5.7}_{-\ 1.9}$ (< 20)	$0.53 \pm 0.16^{+0.15}_{-0.13}$

Browsing through the D^0 listings

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

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

D^0 MASS

The fit includes $D^\pm$, D^0, $D_s^\pm$, $D^{*\pm}$, D^{*0}, $D_s^{*\pm}$, $D_1(2420)^0$, $D_2^*(2460)^0$, and $D_{s1}(2536)^\pm$ mass and mass difference measurements.

Given the recent addition of much more precise measurements, we have omitted all those masses published up through 1990. See any Review before 2015 for those earlier results.

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
1864.83 ±0.05 OUR FIT					
1864.84 ±0.05 OUR AVERAGE					
1864.845±0.025±0.057	63k	[1] TOMARADZE	14		$D^0 \to K^- 2\pi^+ \pi^-$
1864.75 ±0.15 ±0.11		AAIJ	13V	LHCB	$D^0 \to K^+ 2K^- \pi^+$
1864.841±0.048±0.063	4.3k	[2] LEES	13S	BABR	e^+e^- at $\Upsilon(4S)$
1865.30 ±0.33 ±0.23	0.1k	ANASHIN	10A	KEDR	e^+e^- at $\psi(3770)$
1864.847±0.150±0.095	0.3k	CAWLFIELD	07	CLEO	$D^0 \to K_S^0 \phi$

[1] Obtained by analyzing CLEO-c data but not authored by the CLEO Collaboration. The largest source of error in the TOMARADZE 14 value is from the uncertainties in the K^- and K_S^0 masses. The systematic error given above is the addition in quadrature of $\pm0.022 \pm 0.053$ MeV, where the second error is from those mass uncertainties.

[2] The largest source of error in the LEES 13S value is from the uncertainty of the K^+ mass. The quoted systematic error is in fact $\pm0.043 + 3\,(m_{K^+} - 493.677)$, in MeV.

$m_{D^\pm} - m_{D^0}$

The fit includes $D^\pm$, D^0, $D_s^\pm$, $D^{*\pm}$, D^{*0}, $D_s^{*\pm}$, $D_1(2420)^0$, $D_2^*(2460)^0$, and $D_{s1}(2536)^\pm$ mass and mass difference measurements.

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
4.822±0.015 OUR FIT				
4.76 ±0.12 ±0.07	AAIJ	13V	LHCB	$D^+ \to K^+ K^- \pi^+$

D^0 MEAN LIFE

Measurements with an error $> 10 \times 10^{-15}$ s have been omitted from the average.

VALUE (10^{-15} s)	EVTS	DOCUMENT ID		TECN	COMMENT
410.1± 1.5 OUR AVERAGE					
409.6± 1.1± 1.5	210k	LINK	02F	FOCS	γ nucleus, ≈ 180 GeV
407.9± 6.0± 4.3	10k	KUSHNIR...	01	SELX	$K^-\pi^+$, $K^-\pi^+\pi^+\pi^-$
413 ± 3 ± 4	35k	AITALA	99E	E791	$K^-\pi^+$
408.5± $4.1^{+3.5}_{-3.4}$	25k	BONVICINI	99	CLE2	$e^+e^- \approx \Upsilon(4S)$
413 ± 4 ± 3	16k	FRABETTI	94D	E687	$K^-\pi^+$, $K^-\pi^+\pi^+\pi^-$

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

• • • We do not use the following data for averages, fits, limits, etc. • • •

424 ±11 ± 7	5118	FRABETTI	91	E687	$K^-\pi^+$, $K^-\pi^+\pi^+\pi^-$
417 ±18 ±15	890	ALVAREZ	90	NA14	$K^-\pi^+$, $K^-\pi^+\pi^+\pi^-$
388 $^{+23}_{-21}$	641	[1] BARLAG	90C	ACCM	π^- Cu 230 GeV
480 ±40 ±30	776	ALBRECHT	88I	ARG	e^+e^- 10 GeV
422 ± 8 ±10	4212	RAAB	88	E691	Photoproduction
420 ±50	90	BARLAG	87B	ACCM	K^- and π^- 200 GeV

[1] BARLAG 90C estimate systematic error to be negligible.

See the related review(s):
D^0 — $\overline{D}^0$ Mixing

$\left|m_{D_1^0} - m_{D_2^0}\right| = x\,\Gamma$

The D_1^0 and D_2^0 are the mass eigenstates of the D^0 meson, as described in the note on "D^0-$\overline{D}^0$ Mixing," above. The experiments usually present $x \equiv \Delta m/\Gamma$. Then $\Delta m = x\,\Gamma = x\,\hbar/\tau$.

"OUR EVALUATION" comes from CPV allowing averages provided by the Heavy Flavor Averaging Group, see the note on "D^0-$\overline{D}^0$ Mixing."

VALUE (10^{10} $\hbar$ s^{-1})	CL%	DOCUMENT ID		TECN	COMMENT
$0.95^{+0.41}_{-0.44}$ OUR EVALUATION					
0.7 ±0.4 OUR AVERAGE Error includes scale factor of 1.4. See the ideogram below.					
$0.66^{+0.41}_{-0.37}$		[1] AAIJ	19X	LHCB	$D^0 \to K_S^0\pi^+\pi^-$
		[2] AAIJ	18K	LHCB	pp at 7, 8, 13 TeV
− 2.10±1.29±0.41		[3] AAIJ	16V	LHCB	pp at 7 TeV
3.7 ±2.9 ±1.5		[4] LEES	16D	BABR	e^+e^-, 10.6 GeV
		[5] KO	14	BELL	$e^+e^- \to \Upsilon(nS)$
$1.37\pm0.46^{+0.18}_{-0.28}$		[6] PENG	14	BELL	$e^+e^- \to \Upsilon(nS)$
		[7] AALTONEN	13AE	CDF	$p\overline{p}$ at 1.96 TeV
0.39±0.56±0.35		[8] DEL-AMO-SA...	10D	BABR	e^+e^-, 10.6 GeV
• • • We do not use the following data for averages, fits, limits, etc. • • •					
		[9] AAIJ	17AO	LHCB	Repl. by AAIJ 18K
		[10] AAIJ	13CE	LHCB	Repl. by AAIJ 17AO
		[11] AAIJ	13N	LHCB	Repl. by AAIJ 13CE
6.4 $^{+1.4}_{-1.7}$ ±1.0		[12] AUBERT	09AN	BABR	e^+e^- at 10.58 GeV
− 2 $^{+7}_{-6}$		[13] LOWREY	09	CLEO	e^+e^- at $\psi(3770)$
$1.98\pm0.73^{+0.32}_{-0.41}$		[14] ZHANG	07B	BELL	Repl. by PENG 14
< 7	95	[15] ZHANG	06	BELL	e^+e^-
−11 to +22		[14] ASNER	05	CLEO	$e^+e^- \approx$ 10 GeV
< 11	90	BITENC	05	BELL	

Browsing through the D^0 listings

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

D^0 $\quad I(J^P) = \frac{1}{2}(0^-)$

D^0 MASS

The fit includes $D^\pm$, D^0, $D_s^\pm$, $D^{*\pm}$, D^{*0}, $D_s^{*\pm}$, $D_1(2420)^0$, $D_2^*(2460)^0$, and $D_{s1}(2536)^\pm$ mass and mass difference measurements.

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1864.841±0.048±0.063	4.3k	[2] LEES	13S	BABR	$e^+ e^-$ at $\Upsilon(4S)$
1865.30 ±0.33 ±0.23	0.1k	ANASHIN	10A	KEDR	$e^+ e^-$ at $\psi(3770)$
1864.847±0.150±0.095	0.3k	CAWLFIELD	07	CLEO	$D^0 \to K_S^0 \phi$

[1] Obtained by analyzing CLEO-c data but not authored by the CLEO Collaboration. The largest source of error in the TOMARADZE 14 value is from the uncertainties in the K^- and K_S^0 masses. The systematic error given above is the addition in quadrature of $\pm 0.022 \pm 0.053$ MeV, where the second error is from those mass uncertainties.

[2] The largest source of error in the LEES 13S value is from the uncertainty of the K^+ mass. The quoted systematic error is in fact $\pm 0.043 + 3\,(m_{K^+} - 493.677)$, in MeV.

$m_{D^\pm} - m_{D^0}$

The fit includes $D^\pm$, D^0, $D_s^\pm$, $D^{*\pm}$, D^{*0}, $D_s^{*\pm}$, $D_1(2420)^0$, $D_2^*(2460)^0$, and $D_{s1}(2536)^\pm$ mass and mass difference measurements.

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
4.822±0.015 OUR FIT				
4.76 ±0.12 ±0.07	AAIJ	13V	LHCB	$D^+ \to K^+ K^- \pi^+$

D^0 MEAN LIFE

Measurements with an error $> 10 \times 10^{-15}$ s have been omitted from the average.

VALUE (10^{-15} s)	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
410.1± 1.5 OUR AVERAGE					
409.6± 1.1± 1.5	210k	LINK	02F	FOCS	γ nucleus, $\approx$ 180 GeV
407.9± 6.0± 4.3	10k	KUSHNIR...	01	SELX	$K^-\pi^+$, $K^-\pi^+\pi^+\pi^-$
413 ± 3 ± 4	35k	AITALA	99E	E791	$K^-\pi^+$
408.5± 4.1$^{+3.5}_{-3.4}$	25k	BONVICINI	99	CLE2	$e^+e^- \approx \Upsilon(4S)$
413 ± 4 ± 3	16k	FRABETTI	94D	E687	$K^-\pi^+$, $K^-\pi^+\pi^+\pi^-$

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

• • • We do not use the following data for averages, fits, limits, etc. • • •

424 ±11 ± 7	5118	FRABETTI	91	E687	$K^-\pi^+$, $K^-\pi^+\pi^+\pi^-$
417 ±18 ±15	890	ALVAREZ	90	NA14	$K^-\pi^+$, $K^-\pi^+\pi^+\pi^-$
388 $^{+23}_{-21}$					π^- Cu 230 GeV
480 ±40					GeV
422					

$D^0 - \overline{D}^0$ Mixing

VALUE (10^{10} $\hbar$ s^{-1})	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
0.95$^{+0.41}_{-0.44}$ OUR EVALUATION					
0.7 ±0.4 OUR AVERAGE Error includes scale factor of 1.4. See the ideogram below.					
0.66$^{+0.41}_{-0.37}$		[1] AAIJ	19X	LHCB	$D^0 \to K_S^0 \pi^+\pi^-$
		[2] AAIJ	18K	LHCB	pp at 7, 8, 13 TeV
− 2.10±1.29±0.41		[3] AAIJ	16V	LHCB	pp at 7 TeV
3.7 ±2.9 ±1.5		[4] LEES	16D	BABR	e^+e^-, 10.6 GeV
		[5] KO	14	BELL	$e^+e^- \to \Upsilon$(nS)
1.37±0.46$^{+0.18}_{-0.28}$		[6] PENG	14	BELL	$e^+e^- \to \Upsilon$(nS)
		[7] AALTONEN	13AE	CDF	$p\overline{p}$ at 1.96 TeV
0.39±0.56±0.35		[8] DEL-AMO-SA...	10D	BABR	e^+e^-, 10.6 GeV
• • • We do not use the following data for averages, fits, limits, etc. • • •					
		[9] AAIJ	17AO	LHCB	Repl. by AAIJ 18K
		[10] AAIJ	13CE	LHCB	Repl. by AAIJ 17AO
		[11] AAIJ	13N	LHCB	Repl. by AAIJ 13CE
6.4 $^{+1.4}_{-1.7}$ ±1.0		[12] AUBERT	09AN	BABR	e^+e^- at 10.58 GeV
− 2 $^{+7}_{-6}$		[13] LOWREY	09	CLEO	e^+e^- at $\psi(3770)$
1.98±0.73$^{+0.32}_{-0.41}$		[14] ZHANG	07B	BELL	Repl. by PENG 14
< 7	95	[15] ZHANG	06	BELL	e^+e^-
−11 to +22		[14] ASNER	05	CLEO	$e^+e^- \approx$ 10 GeV
< 11	90	BITENC	05	BELL	

Doubly Charmed baryons

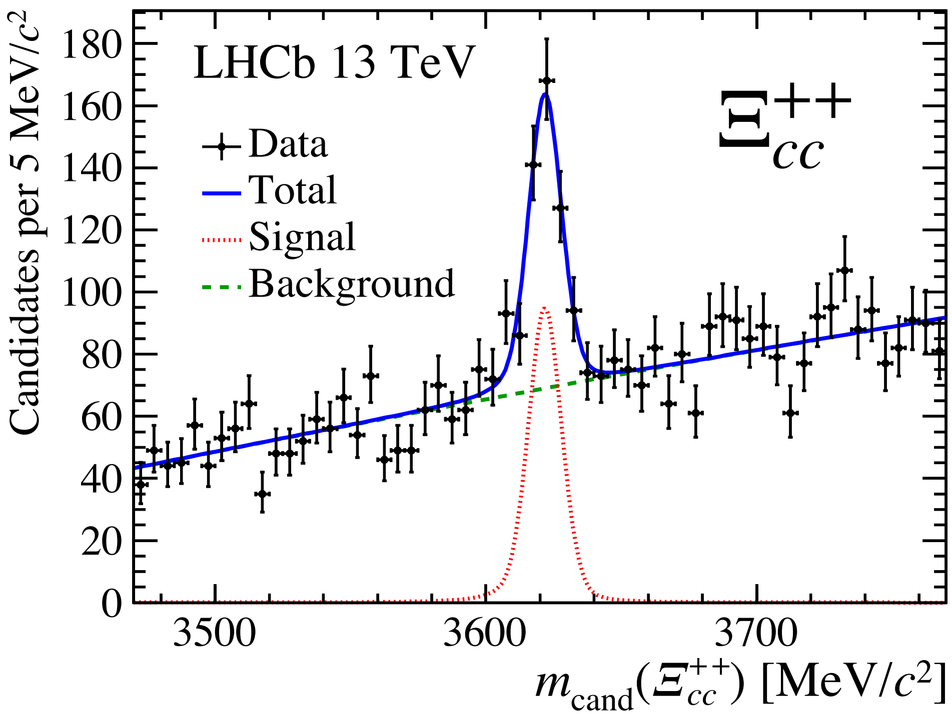
- New cc stats
- New charmed baryons
- Sometimes you get both: New doubly-charmed baryons: Ξ_{cc}^{++}

LHCb: PRL 121 (2018) 16, 162002,
Chin.Phys.C 44 (2020) 2, 022001,
JHEP 02 (2020) 049

Doubly Charmed baryons

- New cc stats
- New charmed baryons
- Sometimes you get both: New doubly-charmed baryons: Ξ_{cc}^{++}

LHCb: PRL 121 (2018) 16, 162002, Chin.Phys.C 44 (2020) 2, 022001, JHEP 02 (2020) 049



LHCb: JHEP 02 (2020) 049

PDG and PuRe

DOE Science
@doescience

The 2,000+ page book of particle physics reference data managed by the Particle Data Group started in 1957 as a simple wallet card. Since then, it's grown to be the reference guide for particle physicists. Get to know this #SCPuReData resource: pdg.lbl.gov

9:56 pm · 26 May 2021 · Sprout Social

PDG

237 authors plus 5 technical associates
174 institutions
26 countries

Booklet survey

Background

- **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.

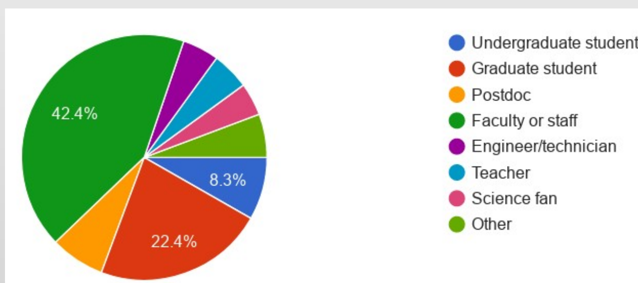
  - Determine whether producing printed PDG Booklet is still useful in view of falling demand for printed products (about -12% / edition)

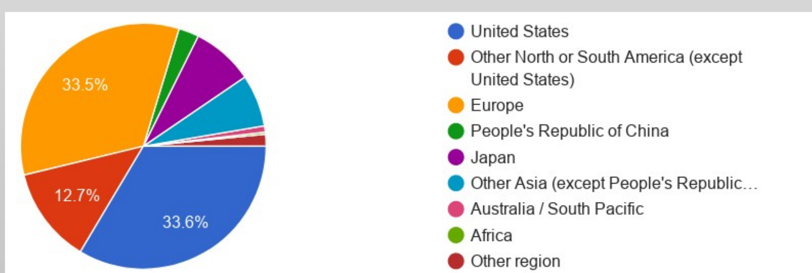
- **Survey timeline**
  - 4/17/2020 Sent to PDG Collaboration, encouraging feedback
  - 4/21/2020 Sent to everyone who ordered Book or Booklet since 2016 and agreed to receiving PDG e-mails
  - **4/22/2020 3,900 responses within 24 hours**
  - 5/6/2020 4,629 responses, closed survey

Booklet survey

Responses

- **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**





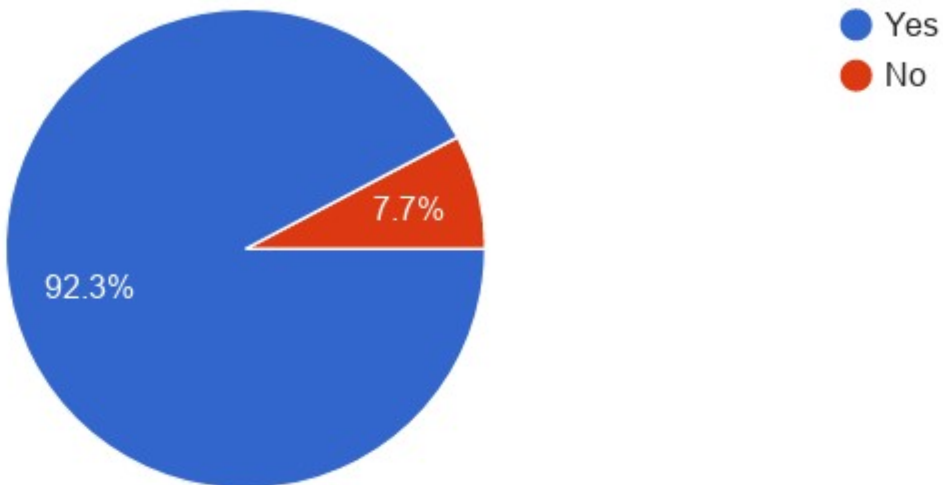
LAWRENCE BERKELEY NATIONAL LABORATORY

Virtual PDG Mini Collaboration Meeting, November 5, 2020 **Juerg Beringer (LBNL), Page 14**

Booklet Survey

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

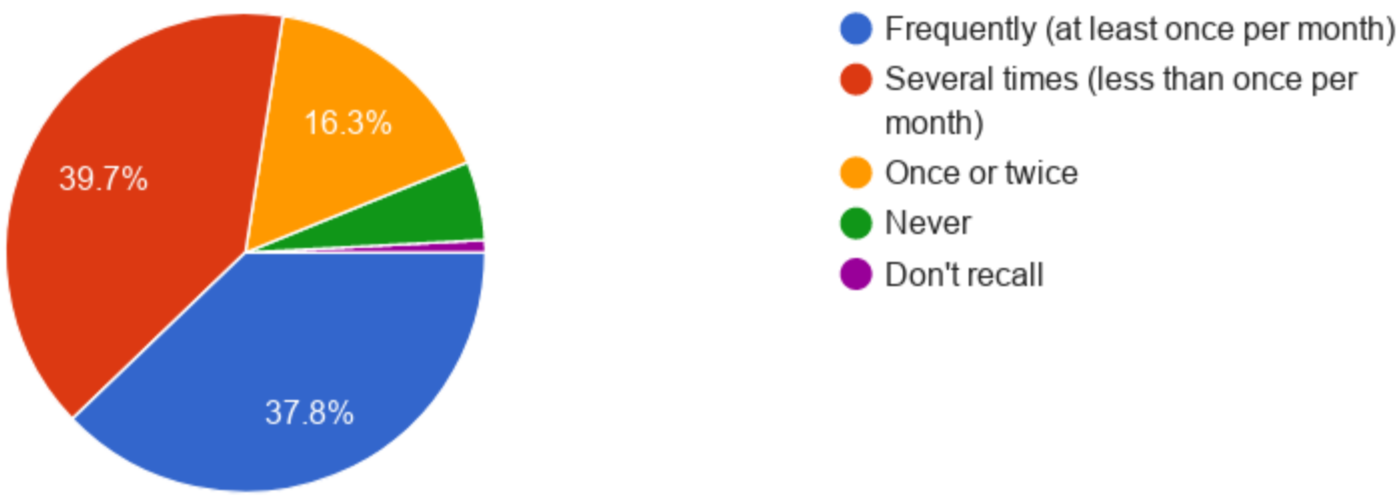
4,629 responses



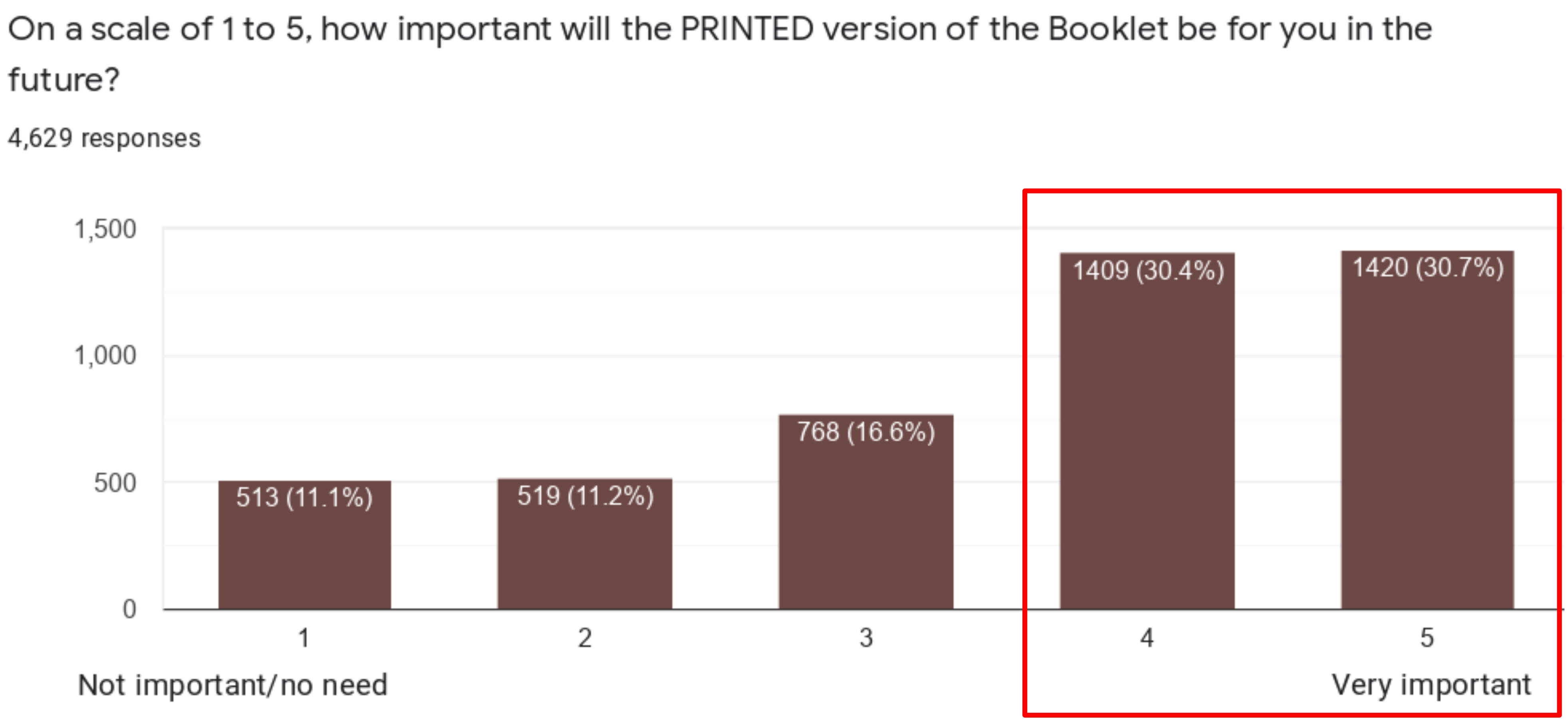
Booklet Survey

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

4,629 responses



Booklet survey



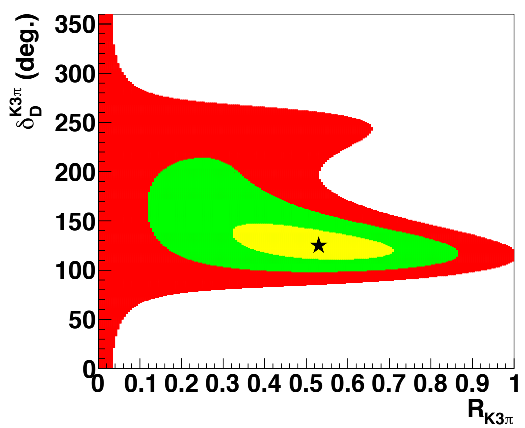
$D^0 \to K^+\pi^-\pi^+\pi^-$ Coherence factor then

$$Re^{-i\delta_D} = c_i + is_i$$

Use interference effects in charm as input to γ

$$\Gamma\left(B^- \to \left(K^+3\pi\right)_D K^-\right) \propto r_B^2 + \left(r_D^{K3\pi}\right)^2 + 2R_{K3\pi} r_B r_D^{K3\pi} \cdot \cos\left(\delta_B + \delta_D^{K3\pi} - \gamma\right)$$

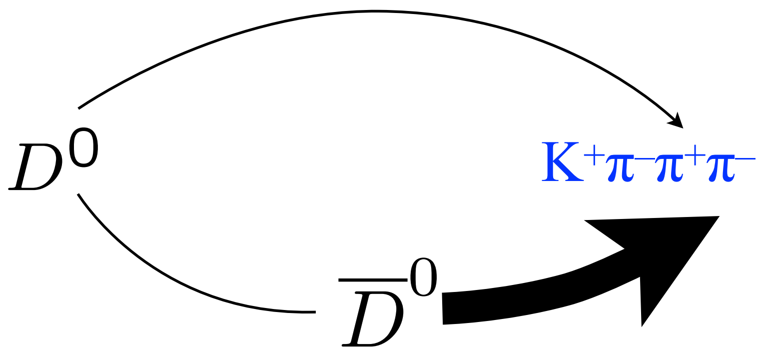
from D-$\bar{D}$ superpositions at CLEO-c

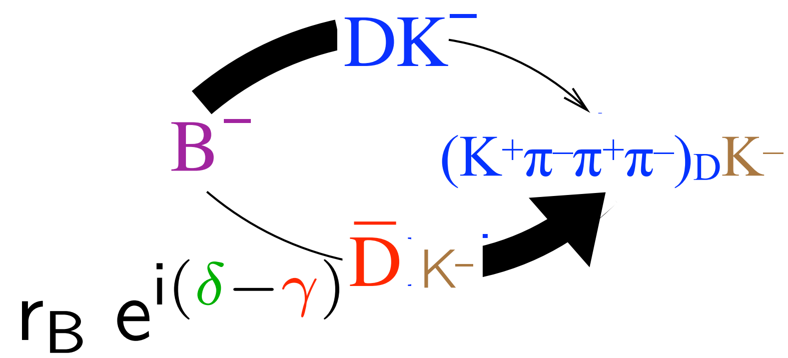


Phys.Lett. B757 (2016) 520-527

CLEO-c input theory: Atwood, Soni: Phys.Rev. D68 (2003) 033003
CLEO-c input: Phys.Rev.D80:031105,2009, update
mixing/gamma theory JHEP 1503 (2015) 169 Phys.Lett. B728 (2014) 296-302

D° Mixing as input to γ from $B^{\pm} \rightarrow DK^{\pm}$





This process is sensitive to the same D-D interference effects that affect this measurement.

LHCb: Phys.Rev.Lett. 116 (2016) no.24, 241801

S. Harnew & JR: Phys.Lett. B728 (2014) 296-302

$D^0 \to K^+\pi^-\pi^+\pi^-$ Coherence factor then

$$Re^{-i\delta_D} = c_i + is_i$$

Use interference effects in charm as input to γ

$$\Gamma\left(B^- \to \left(K^+3\pi\right)_D K^-\right) \propto r_B^2 + \left(r_D^{K3\pi}\right)^2 + 2R_{K3\pi} r_B r_D^{K3\pi} \cdot \cos\left(\delta_B + \delta_D^{K3\pi} - \gamma\right)$$

–

CLEO-c input theory: Atwood, Soni: Phys.Rev. D68 (2003) 033003
CLEO-c input: Phys.Rev.D80:031105,2009, update
mixing/gamma theory JHEP 1503 (2015) 169 Phys.Lett. B728 (2014) 296-302

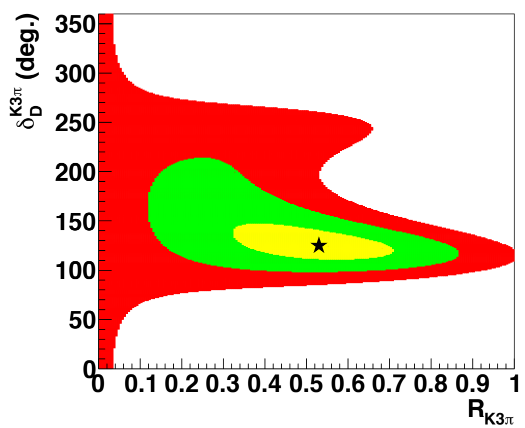
$D^0 \to K^+\pi^-\pi^+\pi^-$ Coherence factor then

$$Re^{-i\delta_D} = c_i + is_i$$

Use interference effects in charm as input to γ

$$\Gamma\left(\mathrm{B}^- \to \left(\mathrm{K}^+3\pi\right)_\mathrm{D}\mathrm{K}^-\right) \propto r_B^2 + \left(r_D^{K3\pi}\right)^2 + 2R_{K3\pi}r_B r_D^{K3\pi}\cdot\cos\left(\delta_B + \delta_D^{K3\pi} - \gamma\right)$$

from D-$\bar{\mathrm{D}}$
superpositions
at CLEO-c



Phys.Lett. B757 (2016) 520-527

CLEO-c input theory: Atwood, Soni: Phys.Rev. D68 (2003) 033003
CLEO-c input: Phys.Rev.D80:031105,2009, update
mixing/gamma theory JHEP 1503 (2015) 169 Phys.Lett. B728 (2014) 296-302

$D^0 \to K^+\pi^-\pi^+\pi^-$ Coherence factor then

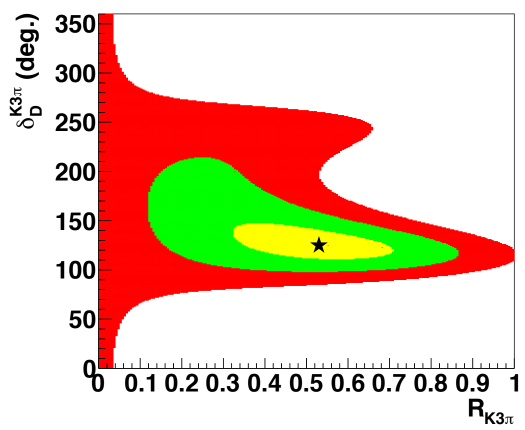
$$Re^{-i\delta_D} = c_i + is_i$$

Use interference effects in charm as input to γ

$$\Gamma\left(B^- \to \left(K^+3\pi\right)_D K^-\right) \propto r_B^2 + \left(r_D^{K3\pi}\right)^2 + 2R_{K3\pi} r_B r_D^{K3\pi} \cdot \cos\left(\delta_B + \delta_D^{K3\pi} - \gamma\right)$$

from D-D̄ superpositions at CLEO-c

Input from charm mixing (LHCb)



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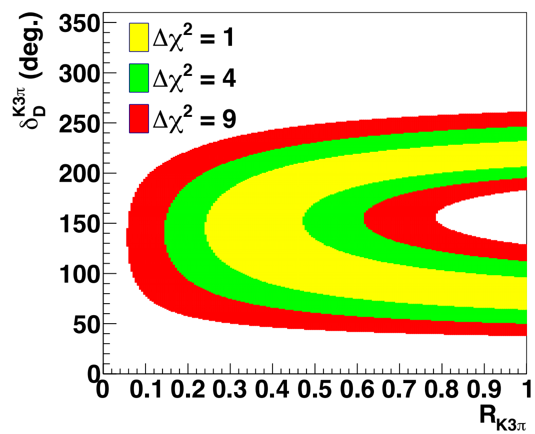


Phys.Lett. B757 (2016) 520-527

PRL 116 (2016) no.24, 241801

CLEO-c input theory: Atwood, Soni: Phys.Rev. D68 (2003) 033003
CLEO-c input: Phys.Rev.D80:031105,2009, update
mixing/gamma theory JHEP 1503 (2015) 169 Phys.Lett. B728 (2014) 296-302

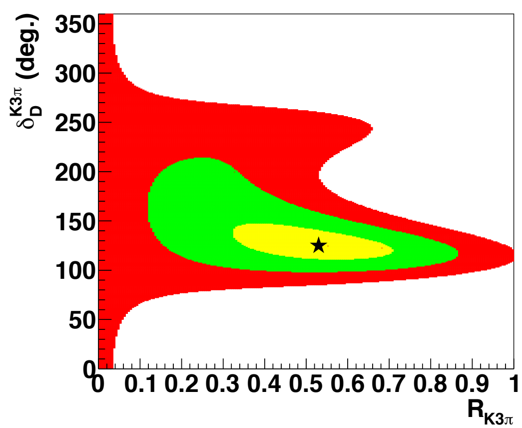
$D^0 \to K^+\pi^-\pi^+\pi^-$ Coherence factor then

$Re^{-i\delta_D} = c_i + is_i$

Use interference effects in charm as input to γ

$$\Gamma\left(B^- \to \left(K^+3\pi\right)_D K^-\right) \propto r_B^2 + \left(r_D^{K3\pi}\right)^2 + 2R_{K3\pi}r_Br_D^{K3\pi}\cdot\cos\left(\delta_B + \delta_D^{K3\pi} - \gamma\right)$$

from D-$\bar{\text{D}}$ superpositions at CLEO-c	Input from charm mixing (LHCb)	Combination:CLEO-c and mixing.



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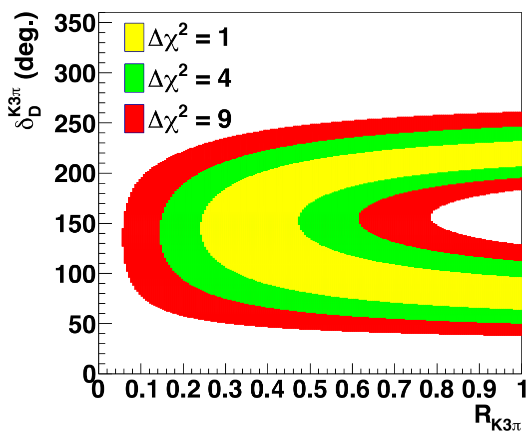

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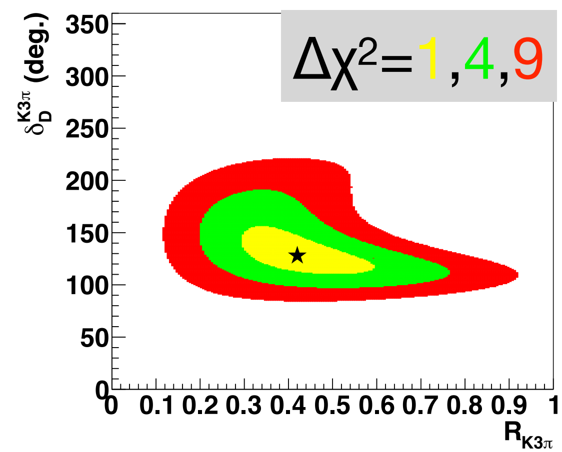


Phys.Lett. B757 (2016) 520-527 | PRL 116 (2016) no.24, 241801 | Phys.Lett. B757 (2016) 520-527

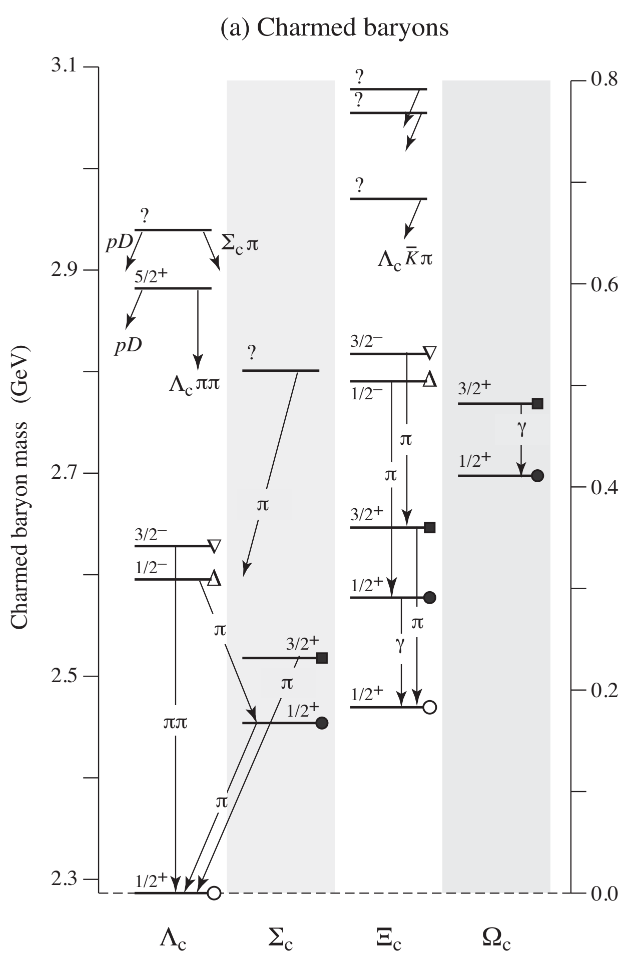
CLEO-c input theory: Atwood, Soni: Phys.Rev. D68 (2003) 033003
CLEO-c input: Phys.Rev.D80:031105,2009, update
mixing/gamma theory JHEP 1503 (2015) 169 Phys.Lett. B728 (2014) 296-302

Charmed Baryons

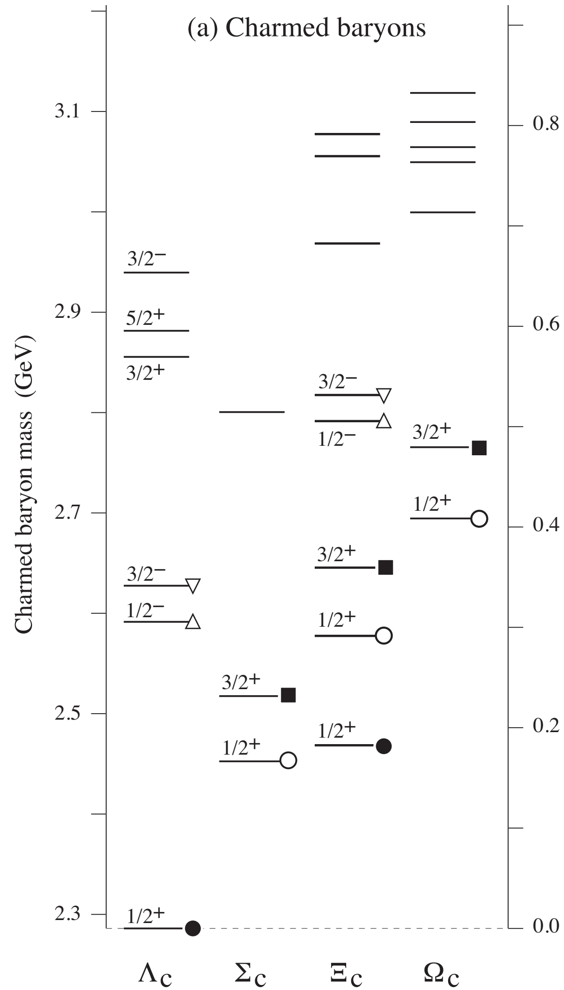
84. Charmed Baryons

Revised in part June 2020 by D.J. Robinson (LBNL).

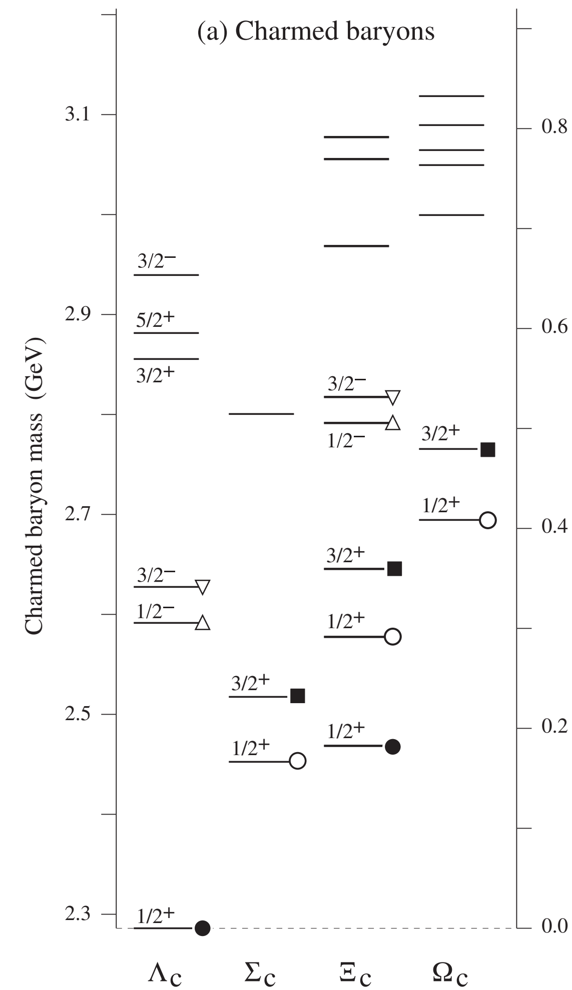
PDG 2017
(revised 2012)



PDG 2018
(revised March 2018)



PDG 2020
(revised June 2020)



Coherence factors: average only model-independent measurements.

$D^0 \to K^-\pi^-2\pi^+$ COHERENCE FACTOR $R_{K3\pi}$

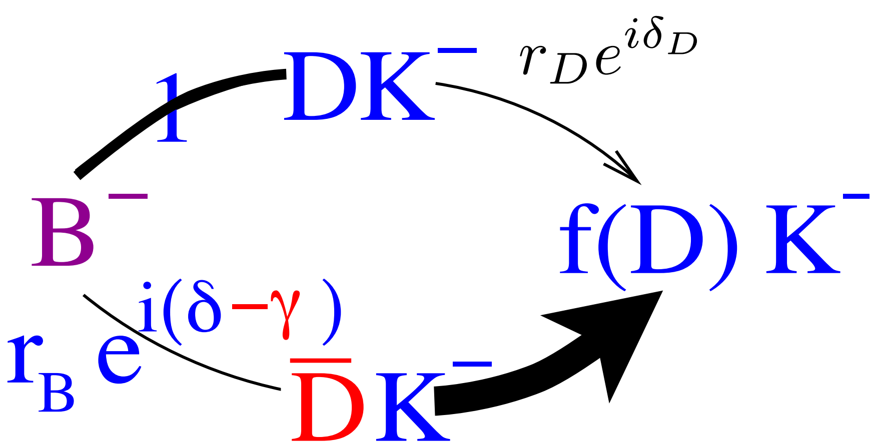
See the note on 'D^0-$\overline{D}^0$ Mixing' for the definition. $R_{K3\pi}$ can have any value between 0 and 1. A value near 1 indicates the decay is dominated by a few intermediate states with limited interference.

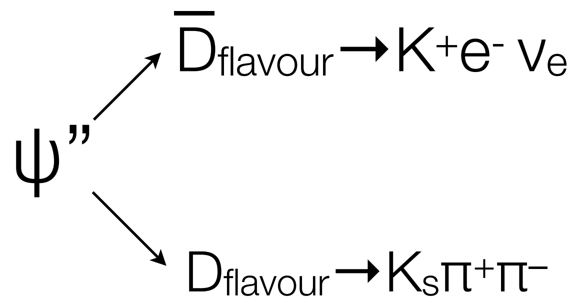
VALUE	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
$\mathbf{0.53\ ^{+0.18}_{-0.21}}$		[1,2,3] EVANS	16		$e^+e^- \to D^0\overline{D}^0$ at $\psi(3770)$, pp at 7,8 TeV

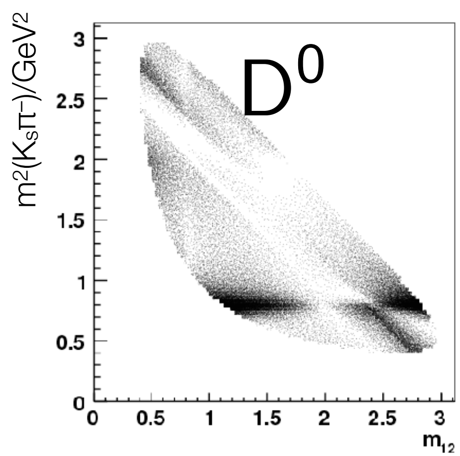
• • • We do not use the following data for averages, fits, limits, etc. • • •

$0.458\pm0.010\pm0.023$	0.9M,3k	[4] AAIJ	18AI	LHCB	amplitude models
$0.32\ ^{+0.20}_{-0.28}$		[1,3] LIBBY	14		Repl. by EVANS 16
$0.36\ ^{+0.24}_{-0.30}$		[5] LOWREY	09	CLEO	Repl. by LIBBY 14

Charm input to CPV in B





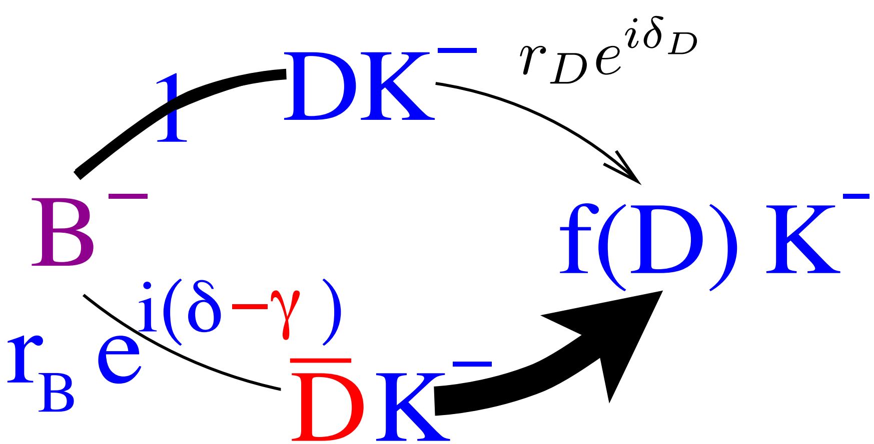


simulated data

$m^2(K_S\pi^+)/GeV^2$

Gronau, Wyler Phys.Lett.B265:172-176,1991, (GLW), Gronau, London Phys.Lett.B253:483-488,1991 **(GLW)** Atwood, Dunietz and Soni Phys.Rev.Lett. 78 (1997) 3257-3260 (ADS) Giri, Grossman, Soffer and Zupan Phys.Rev. D68 (2003) 054018 Belle Collaboration Phys.Rev. D70 (2004) 072003

Charm input to CPV in B

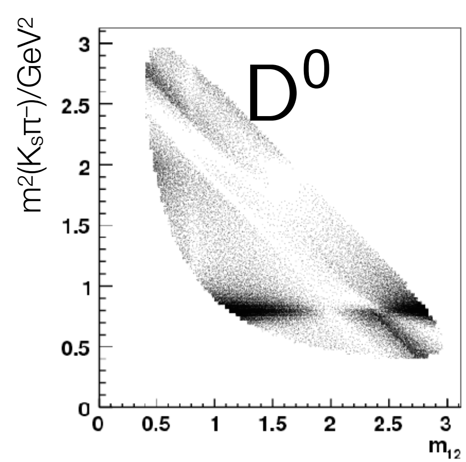


$\psi'' \to \bar{D}_{flavour} \to K^+ e^- \nu_e$

$\psi'' \to D_{flavour} \to K_S \pi^+ \pi^-$

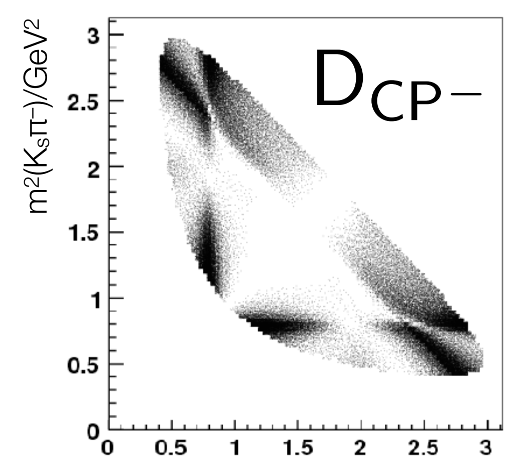
$\psi'' \to D_{CP+} \to KK$

$\psi'' \to D_{CP-} \to K_S \pi^+ \pi^-$



simulated data

$m^2(K_S\pi^+)/GeV^2$

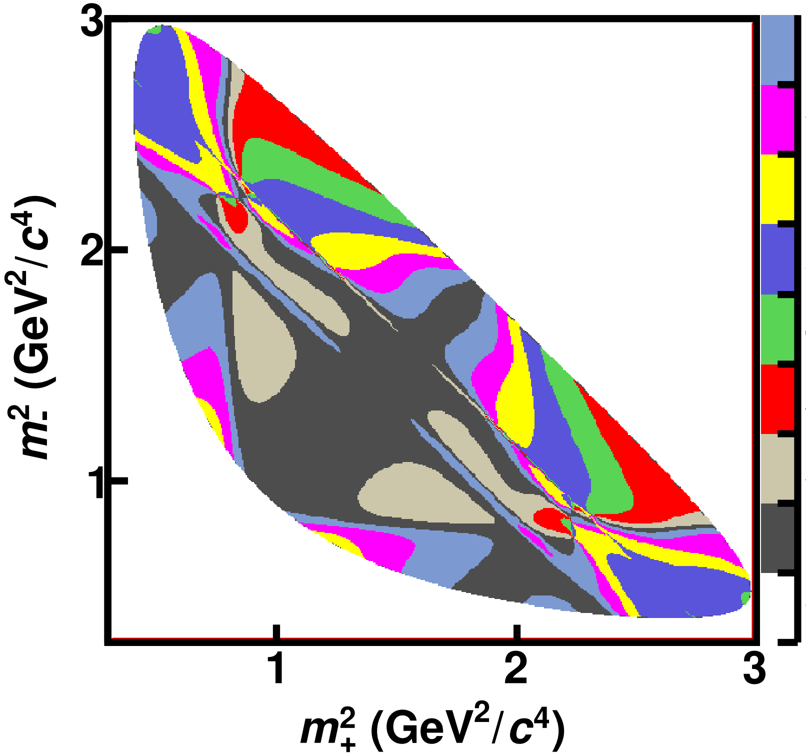


simulated data

$m^2(K_S\pi^+)/GeV^2$

Gronau, Wyler Phys.Lett.B265:172-176,1991, (GLW), Gronau, London Phys.Lett.B253:483-488,1991 **(GLW)** Atwood, Dunietz and Soni Phys.Rev.Lett. 78 (1997) 3257-3260 (ADS) Giri, Grossman, Soffer and Zupan Phys.Rev. D68 (2003) 054018 Belle Collaboration Phys.Rev. D70 (2004) 072003

Biggest change for charm inputs to CPV in B since 2018: BES III



$$c_i = \langle \cos(\delta_i) \rangle$$

$$s_i = \langle \sin(\delta_i) \rangle$$