Systematic uncertainties of $\chi_{c1}(3872)$ lineshape analysis

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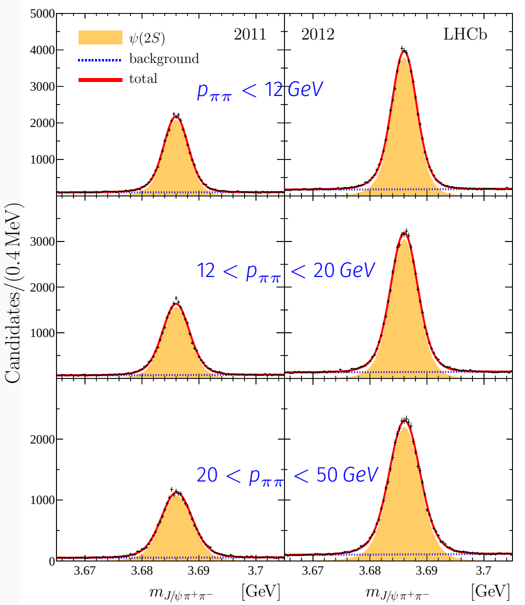
Inclusive analysis - Breit Wigner fit

[PRD102(2020)092005]

- Mass resolution depends on di-pion momentum $p_{\pi\pi}$
- use three momentum bins per data taking period
- **Momentum scale and resolution calibrated on ψ(2S)**
- Momentum scale extrapolated to signal region using simulation
- Momentum scale uncertainty corresponds to a mass-shift of the observed signal relative to the $\psi(2S)$ of ~ 0.066 MeV



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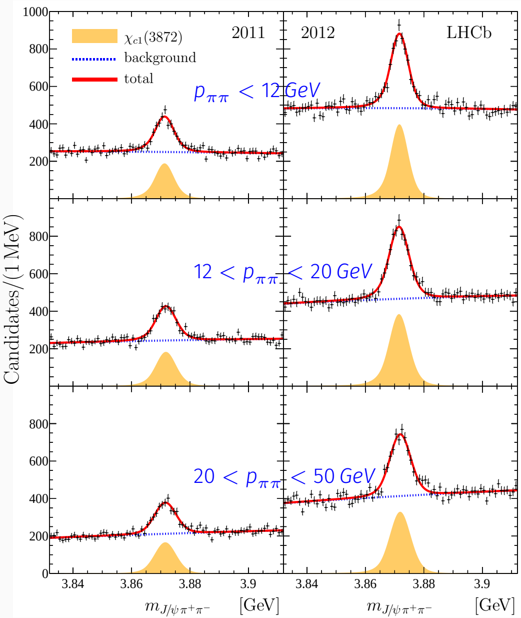


Flatté lineshape for the $\chi_{c1}(3872)$ [PRD80(2009)074004]

Threshold at

$3871.70 \pm 0.11\,\mathrm{MeV}$

Fit parameters

Amplitude $F(E) = -\frac{1}{2k_1}\frac{g_1 k_1}{D(E)},$

$E_f = m_0 - m_{D^0\bar{D}^{0*}}$

DD* coupling (g1=g2) ← Isospin symmetry

$$D(E) = \begin{cases} E - E_f - \frac{g_1\kappa_1}{2} - \frac{g_2\kappa_2}{2} + i\frac{\Gamma(E)}{2}, & E < 0 \\ E - E_f - \frac{g_2\kappa_2}{2} + i\left(\frac{g_1 k_1}{2} + \frac{\Gamma(E)}{2}\right), & 0 < E < \delta \\ E - E_f + i\left(\frac{g_1 k_1}{2} + \frac{g_2 k_2}{2} + \frac{\Gamma(E)}{2}\right), & E > \delta \end{cases}$$

Both $D^0\bar{D}^{0*}$ and D^+D^{-*} channels

Dynamic width

All other modes

$$\Gamma(E) = \Gamma_{\pi^+\pi^-J/\psi}(E) + \Gamma_{\pi^+\pi^-\pi^0 J/\psi}(E) + \Gamma_0,$$

$k_1 = \sqrt{2\mu_1 E}, \quad \kappa_1 = \sqrt{-2\mu_1 E}, \quad k_2 = \sqrt{2\mu_2(E-\delta)}, \quad \kappa_2 = \sqrt{2\mu_2(\delta - E)}.$

$$\Gamma_{\pi^+\pi^-J/\psi}(E) = f_\rho \int_{2m_\pi}^{M-m_{J/\psi}} \frac{dm}{2\pi}\frac{q(m)\Gamma_\rho}{(m-m_\rho)^2 + \Gamma_\rho^2/4},$$

$$\Gamma_{\pi^+\pi^-\pi^0 J/\psi}(E) = f_\omega \int_{3m_\pi}^{M-m_{J/\psi}} \frac{dm}{2\pi}\frac{q(m)\Gamma_\omega}{(m-m_\omega)^2 + \Gamma_\omega^2/4},$$

$$q(m) = \sqrt{\frac{(M^2-(m+m_{J/\psi})^2)(M^2-(m-m_{J/\psi})^2)}{4M^2}}$$

differential branching fractions:

$$\frac{dBr(B \to K\pi^+\pi^-J/\psi)}{dE} = \mathcal{B}\frac{1}{2\pi}\frac{\Gamma_{\pi^+\pi^-J/\psi}(E)}{|D(E)|^2},$$

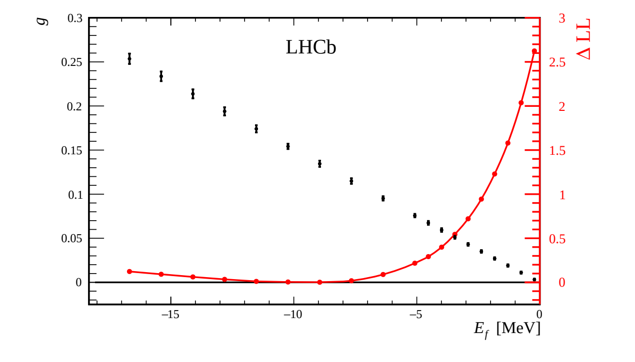
$$\frac{dBr(B \to K\pi^+\pi^-\pi^0 J/\psi)}{dE} = \mathcal{B}\frac{1}{2\pi}\frac{\Gamma_{\pi^+\pi^-\pi^0 J/\psi}(E)}{|D(E)|^2}.$$

- Constraints on partial widths, consistent with existing data

$$\Gamma(J/\psi\rho) = \Gamma(J/\psi\omega)$$

$$\frac{\Gamma(J/\psi\rho)}{\Gamma(D^0 D^{0*})} = 0.11 \pm 0.03$$

- Will cause shape to be different from Breit-Wigner
- 4 fit parameters: m_0, g, f_ρ, Γ_0
- Fix $m_0 = 3864.5$ MeV



$$\frac{dg}{dE_f} = (-15.11 \pm 0.16)\text{GeV}^{-1}$$

offset consistent with zero

Very shallow likelihood minimum at $E_f \approx -10$ MeV.
ΔLL rises back to 1 around -270 MeV

Flatté parameters and comparison to Breit-Wigner [PRD102(2020)092005]

g	$f_\rho \times 10^3$	Γ_0 [MeV]
$0.108 \pm 0.003\,^{+0.005}_{-0.006}$	$1.8 \pm 0.6\,^{+0.7}_{-0.6}$	$1.4 \pm 0.4 \pm 0.6$

Shape parameters:

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

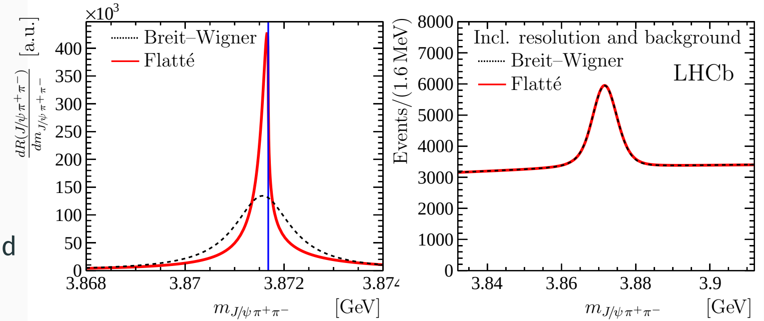
- $J/\psi\pi\pi$ data alone cannot distinguish line shapes
- Flatté narrower than BW by factor 5

Systematic uncertainties on g

- Momentum scale
- Threshold mass

Small effect:
Resolution+Bkg model and D^{0*} width

Systematic uncertainties quoted do not include scaling!



Effect of uncertainty of E_f on g

Both the momentum scale uncertainty and the uncertainty on the threshold location act in similar way, by changing the obtained value of E_f.

- m_0 was kept fix
- Shifting the data downwards $\Rightarrow$ g has to compensate the shift of the peak by getting smaller.
- Shifting the data upwards $\Rightarrow$ g has to compensate accordingly.
- This is what we observe.
- Systematics were only evaluated at fixed m_0
  Cannot distinguish between change in slope and change in offset of $g(E_f)$

Ongoing activities: provide full uncertainties on g, including limits obtained from scaling.

Future: very interested in reanalysis, need to find a student. Possibility for an associate project.