Recent developments in charmed baryon spectroscopy

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Known Charmed Baryon States

$B_c = c + \text{diquark}$

Quark content of diquark:
- $qq$ with isospin 0 (flavor antisymmetric) — $\Lambda_c$ family;
- $qq$ with isospin 1 (flavor symmetric) — $\Sigma_c$ family;
- $qs$ with isospin $\frac{1}{2}$ — $\Xi_c$ family;
- $ss$ with isospin 0 (flavor symmetric) — $\Omega_c$ family.
<table>
<thead>
<tr>
<th>State</th>
<th>Decay mode</th>
<th>Mass, MeV/c²</th>
<th>Width, MeV</th>
<th>J/P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ξ⁺</td>
<td>Ξ⁺γ, Ξ⁰γ</td>
<td>2575.7 ± 3.0</td>
<td>2577.9 ± 2.9</td>
<td>1/2 +</td>
</tr>
<tr>
<td>Ξ⁺(2645)⁺</td>
<td>Ξ⁺γ, Ξ⁰γ</td>
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</tr>
<tr>
<td>Ξ⁺(2930)⁰</td>
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</tr>
<tr>
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<td>2577.9 ± 2.9</td>
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<td>Ξ⁺(3080)⁺</td>
<td>Ξ⁺γ, Ξ⁰γ</td>
<td>2575.7 ± 3.0</td>
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<td>2577.9 ± 2.9</td>
<td>1/2 +</td>
</tr>
</tbody>
</table>
Decays to $\Xi_c$: $\Xi'_c$ Isodoublet

$\Xi_c(2645)^+$
$\Xi_c(2645)^0$
$\Xi_c(2790)^+$
$\Xi_c(2790)^0$
$\Xi_c(2815)^+$
$\Xi_c(2815)^0$
$\Xi_c(2930)^0$
$\Xi_c(2970)^+$
$\Xi_c(2970)^0$
$\Xi_c(3055)^+$
$\Xi_c(3055)^0$
$\Xi_c(3080)^+$
$\Xi_c(3080)^0$

$\Xi'_c \rightarrow \Xi_c \gamma$

$M_{\Xi'_c^+} - M_{\Xi_c^+} = (110.5 \pm 0.1[stat.] \pm 0.4[syst.]) \text{ MeV/c}^2$

$M_{\Xi'_c^0} - M_{\Xi_c^0} = (108.3 \pm 0.1[stat.] \pm 0.4[syst.]) \text{ MeV/c}^2$

[J. Yelton et al. (Belle Collaboration), Phys. Rev. D 94, 052011 (2016)]
Decays to $\Xi_c$: $\Xi_c(2790)$ Isodoublet

$\Xi_c(2790) \rightarrow \Xi'_c \pi$

$M_{\Xi_c(2790)}^+ - M_{\Xi'_c(2790)} = (213.2 \pm 0.2[\text{stat.}] \pm 0.1[\text{syst.}]) \text{ MeV}/c^2$

$\Gamma_{\Xi_c(2790)}^+ = (8.9 \pm 0.6[\text{stat.}] \pm 0.8[\text{syst.}]) \text{ MeV}$

$M_{\Xi_c(2790)}^0 - M_{\Xi'_c(2790)} = (215.7 \pm 0.2[\text{stat.}] \pm 0.1[\text{syst.}]) \text{ MeV}/c^2$

$\Gamma_{\Xi_c(2790)}^0 = (10.0 \pm 0.7[\text{stat.}] \pm 0.8[\text{syst.}]) \text{ MeV}$

[J. Yelton et al. (Belle Collaboration), Phys. Rev. D 94, 052011 (2016)]
Decays to $\Xi_c$: $\Xi_c(2645)$ Isodoublet

$\Xi_c(2645) \equiv \Xi_c^*$

$\Xi_c(2645) \rightarrow \Xi_c \pi$

$M_{\Xi_c(2645)^+} - M_{\Xi_c^0} = (174.66 \pm 0.06 [\text{stat.}] \pm 0.07 [\text{syst.}]) \text{ MeV}/c^2$

$\Gamma_{\Xi_c(2645)^+} = (2.06 \pm 0.13 [\text{stat.}] \pm 0.13 [\text{syst.}]) \text{ MeV}$

$M_{\Xi_c(2645)^0} - M_{\Xi_c^+} = (178.46 \pm 0.07 [\text{stat.}] \pm 0.07 [\text{syst.}]) \text{ MeV}/c^2$

$\Gamma_{\Xi_c(2645)^0} = (2.35 \pm 0.18 [\text{stat.}] \pm 0.13 [\text{syst.}]) \text{ MeV}$

[J. Yelton et al. (Belle Collaboration), Phys. Rev. D 94, 052011 (2016)]
Decays to $\Xi_c$: $\Xi_c(2815)$ Isodoublet

$\Xi_c(2815) \rightarrow \Xi_c^\ast \pi$

$M_{\Xi_c(2815)^+} - M_{\Xi_c^+} = (348.80 \pm 0.08{[\text{stat.}]} \pm 0.06{[\text{syst.}]) \text{ MeV/c}^2$

$\Gamma_{\Xi_c(2815)^+} = (2.43 \pm 0.20{[\text{stat.}]} \pm 0.17{[\text{syst.}]) \text{ MeV}$

$M_{\Xi_c(2815)^0} - M_{\Xi_c^0} = (349.35 \pm 0.08{[\text{stat.}]} \pm 0.07{[\text{syst.}]) \text{ MeV/c}^2$

$\Gamma_{\Xi_c(2815)^0} = (2.54 \pm 0.18{[\text{stat.}]} \pm 0.17{[\text{syst.}]) \text{ MeV}$

[J. Yelton et al. (Belle Collaboration), Phys. Rev. D 94, 052011 (2016)]
Decays to $\Xi_c$: $\Xi_c(2970)$ Isodoublet

$\Xi_c(2970) \rightarrow \Xi_c^*\pi$

$M_{\Xi_c(2970)^+} - M_{\Xi_c^+} = (498.1 \pm 0.8[\text{stat.}] \pm 0.2[\text{syst.}])$ MeV/c$^2$

$\Gamma_{\Xi_c(2970)^+} = (28.1 \pm 2.4[\text{stat.}])^{+1.0}_{-5.0}[\text{syst.}]$ MeV

$M_{\Xi_c(2970)^0} - M_{\Xi_c^0} = (499.9 \pm 0.7[\text{stat.}] \pm 0.2[\text{syst.}])$ MeV/c$^2$

$\Gamma_{\Xi_c(2970)^0} = (30.3 \pm 2.3[\text{stat.}])^{+1.0}_{-1.8}[\text{syst.}]$ MeV

[J. Yelton et al. (Belle Collaboration), Phys. Rev. D 94, 052011 (2016)]
### $\Xi_c$ Family: Decays to $\Xi_c$

<table>
<thead>
<tr>
<th>Particle</th>
<th>Yield</th>
<th>Mass</th>
<th>$M - M(\Xi_c)$</th>
<th>$M - M(\Xi'_c)$</th>
<th>Width</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Xi_c^{'+}$</td>
<td>7055 ± 211</td>
<td>2578.4 ± 0.1 ± 0.4$^{+0.3}_{-0.4}$ 2575.6 ± 3.0</td>
<td>110.5 ± 0.1 ± 0.4</td>
<td>107.8 ± 3.0</td>
<td>2.06 ± 0.13 ± 0.13</td>
</tr>
<tr>
<td>PDG</td>
<td></td>
<td>2579.2 ± 0.1 ± 0.4$^{+0.3}_{-0.4}$ 2577.9 ± 2.9</td>
<td>108.3 ± 0.1 ± 0.4</td>
<td>107.0 ± 2.9</td>
<td>2.6 ± 0.2 ± 0.4</td>
</tr>
<tr>
<td>$\Xi_c^{0}$</td>
<td>11560 ± 276</td>
<td>2545.58 ± 0.06 ± 0.07$^{+0.28}_{-0.40}$ 2645.9 ± 0.5</td>
<td>174.66 ± 0.06 ± 0.07</td>
<td>175.0 ± 0.6</td>
<td>2.35 ± 0.18 ± 0.13</td>
</tr>
<tr>
<td>PDG</td>
<td></td>
<td>2646.43 ± 0.07 ± 0.07$^{+0.28}_{-0.40}$ 2645.9 ± 0.5</td>
<td>178.46 ± 0.07 ± 0.07</td>
<td>178.0 ± 0.6</td>
<td>&lt; 5.5</td>
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<tr>
<td>$\Xi_c(2645)^+$</td>
<td>1260 ± 40</td>
<td>2791.6 ± 0.2 ± 0.1 ± 0.4$^{+0.3}_{-0.4}$ 2789.8 ± 3.2</td>
<td>320.7 ± 0.2 ± 0.1 ± 0.4</td>
<td>318.2 ± 3.2</td>
<td>8.9 ± 0.6 ± 0.8</td>
</tr>
<tr>
<td>PDG</td>
<td></td>
<td>2794.9 ± 0.3 ± 0.1 ± 0.4$^{+0.3}_{-0.4}$ 2791.9 ± 3.3</td>
<td>323.8 ± 0.2 ± 0.1 ± 0.4</td>
<td>324.0 ± 3.3</td>
<td>&lt; 15</td>
</tr>
<tr>
<td>$\Xi_c(2645)^0$</td>
<td>975 ± 36</td>
<td>2816.73 ± 0.08 ± 0.06$^{+0.28}_{-0.40}$ 2816.6 ± 0.9</td>
<td>348.80 ± 0.08 ± 0.06</td>
<td>348.7 ± 0.9</td>
<td>10.0 ± 0.7 ± 0.8</td>
</tr>
<tr>
<td>PDG</td>
<td></td>
<td>2820.20 ± 0.08 ± 0.07$^{+0.28}_{-0.40}$ 2819.6 ± 1.2</td>
<td>349.35 ± 0.08 ± 0.07</td>
<td>348.8 ± 1.2</td>
<td>&lt; 12</td>
</tr>
<tr>
<td>$\Xi_c(2790)^+$</td>
<td>2231 ± 103</td>
<td>2966.0 ± 0.8 ± 0.2$^{+0.3}_{-0.4}$ 2970.7 ± 2.2</td>
<td>498.1 ± 0.8 ± 0.2</td>
<td>498.1 ± 0.8 ± 0.2</td>
<td></td>
</tr>
<tr>
<td>PDG</td>
<td></td>
<td>2970.8 ± 0.7 ± 0.2$^{+0.3}_{-0.4}$ 2968.0 ± 2.6 ± 0.5</td>
<td>499.9 ± 0.7 ± 0.2</td>
<td>499.9 ± 0.7 ± 0.2</td>
<td></td>
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<tr>
<td>$\Xi_c(2790)^0$</td>
<td>1241 ± 72</td>
<td>2816.73 ± 0.08 ± 0.06$^{+0.28}_{-0.40}$ 2816.6 ± 0.9</td>
<td>348.80 ± 0.08 ± 0.06</td>
<td>348.7 ± 0.9</td>
<td>2.43 ± 0.20 ± 0.17</td>
</tr>
<tr>
<td>PDG</td>
<td></td>
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<td>349.35 ± 0.08 ± 0.07</td>
<td>348.8 ± 1.2</td>
<td>&lt; 3.5</td>
</tr>
<tr>
<td>$\Xi_c(2815)^+$</td>
<td>941 ± 35</td>
<td>2966.0 ± 0.8 ± 0.2$^{+0.3}_{-0.4}$ 2970.7 ± 2.2</td>
<td>498.1 ± 0.8 ± 0.2</td>
<td>498.1 ± 0.8 ± 0.2</td>
<td></td>
</tr>
<tr>
<td>PDG</td>
<td></td>
<td>2970.8 ± 0.7 ± 0.2$^{+0.3}_{-0.4}$ 2968.0 ± 2.6 ± 0.5</td>
<td>499.9 ± 0.7 ± 0.2</td>
<td>499.9 ± 0.7 ± 0.2</td>
<td></td>
</tr>
<tr>
<td>$\Xi_c(2815)^0$</td>
<td>1258 ± 40</td>
<td>2816.73 ± 0.08 ± 0.06$^{+0.28}_{-0.40}$ 2816.6 ± 0.9</td>
<td>348.80 ± 0.08 ± 0.06</td>
<td>348.7 ± 0.9</td>
<td>2.54 ± 0.18 ± 0.17</td>
</tr>
<tr>
<td>PDG</td>
<td></td>
<td>2820.20 ± 0.08 ± 0.07$^{+0.28}_{-0.40}$ 2819.6 ± 1.2</td>
<td>349.35 ± 0.08 ± 0.07</td>
<td>348.8 ± 1.2</td>
<td>&lt; 6.5</td>
</tr>
<tr>
<td>$\Xi_c(2970)^+$</td>
<td>916 ± 55</td>
<td>2966.0 ± 0.8 ± 0.2$^{+0.3}_{-0.4}$ 2970.7 ± 2.2</td>
<td>498.1 ± 0.8 ± 0.2</td>
<td>498.1 ± 0.8 ± 0.2</td>
<td></td>
</tr>
<tr>
<td>PDG</td>
<td></td>
<td>2970.8 ± 0.7 ± 0.2$^{+0.3}_{-0.4}$ 2968.0 ± 2.6 ± 0.5</td>
<td>499.9 ± 0.7 ± 0.2</td>
<td>499.9 ± 0.7 ± 0.2</td>
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<tr>
<td>$\Xi_c(2970)^0$</td>
<td>1443 ± 75</td>
<td>2816.73 ± 0.08 ± 0.06$^{+0.28}_{-0.40}$ 2816.6 ± 0.9</td>
<td>348.80 ± 0.08 ± 0.06</td>
<td>348.7 ± 0.9</td>
<td>28.1 ± 2.4$^{+1.0}_{-5.0}$</td>
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<tr>
<td>PDG</td>
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<td>2820.20 ± 0.08 ± 0.07$^{+0.28}_{-0.40}$ 2819.6 ± 1.2</td>
<td>349.35 ± 0.08 ± 0.07</td>
<td>348.8 ± 1.2</td>
<td>17.9 ± 3.5</td>
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<td>2966.0 ± 0.8 ± 0.2$^{+0.3}_{-0.4}$ 2970.7 ± 2.2</td>
<td>498.1 ± 0.8 ± 0.2</td>
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<td>2970.8 ± 0.7 ± 0.2$^{+0.3}_{-0.4}$ 2968.0 ± 2.6 ± 0.5</td>
<td>499.9 ± 0.7 ± 0.2</td>
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<td>2816.73 ± 0.08 ± 0.06$^{+0.28}_{-0.40}$ 2816.6 ± 0.9</td>
<td>348.80 ± 0.08 ± 0.06</td>
<td>348.7 ± 0.9</td>
<td>30.3 ± 2.3$^{+1.0}_{-1.8}$</td>
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<td></td>
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<td>2820.20 ± 0.08 ± 0.07$^{+0.28}_{-0.40}$ 2819.6 ± 1.2</td>
<td>349.35 ± 0.08 ± 0.07</td>
<td>348.8 ± 1.2</td>
<td>20 ± 7</td>
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</tbody>
</table>

[J. Yelton et al. (Belle Collaboration), Phys. Rev. D 94, 052011 (2016)]
Family: Decays to $\Lambda_c(\Sigma_c)$

\[ B^- \rightarrow \Lambda_c^+ \overline{\Lambda}_c^- K^- \]

\[ m_{\Xi_c(2930)^0} = (2931 \pm 3[\text{stat.}] \pm 5[\text{syst.}]) \text{ MeV}/c^2 \]

\[ \Gamma_{\Xi_c(2930)^0} = (36 \pm 7[\text{stat.}] \pm 11[\text{syst.}]) \text{ MeV} \]

\[ m_{\Xi_c(2930)^0} = (2928.9 \pm 3.0[\text{stat.}]^{+0.9}_{-12.0}[\text{syst.}]) \text{ MeV}/c^2 \]

\[ \Gamma_{\Xi_c(2930)^0} = (19.5 \pm 8.4[\text{stat.}]^{+5.9}_{-7.9}[\text{syst.}]) \text{ MeV} \]

[B. Aubert et al. (BaBar Collaboration), Phys. Rev. D 77, 031101 (2008)]

[Y.B. Li, C.P. Shen et al. (Belle Collaboration), Eur. Phys. J. C 78, 252 (2018)]
\( \Xi_c \) Family: Decays to \( \Lambda_c(\Sigma_c) \)

<table>
<thead>
<tr>
<th>Particle</th>
<th>Mass (MeV/c^2)</th>
<th>Width (MeV/c^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \Xi_c(2970)^+ )</td>
<td>2974.9 ± 1.5 ± 2.1</td>
<td>14.8 ± 2.5 ± 4.1</td>
</tr>
<tr>
<td>( \Xi_c(3055)^+ )</td>
<td>3058.1 ± 1.0 ± 2.1</td>
<td>9.7 ± 3.4 ± 3.3</td>
</tr>
<tr>
<td>( \Xi_c(3080)^+(\Sigma_c) )</td>
<td>3077.9 ± 0.4 ± 0.7</td>
<td>3.2 ± 1.3 ± 1.3</td>
</tr>
<tr>
<td>( \Xi_c(3080)^+(\Sigma_c^*) )</td>
<td>3076.9 ± 0.3 ± 0.2</td>
<td>2.4 ± 0.9 ± 1.6</td>
</tr>
</tbody>
</table>

**$\Xi_c$ Family: Decays to $\Lambda_c(\Sigma_c)$**

<table>
<thead>
<tr>
<th>$\Xi_c$</th>
<th>Mass (MeV/$c^2$)</th>
<th>Width (MeV)</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Xi_c(3123)^+$</td>
<td>$3122.9 \pm 1.3 \pm 0.3$</td>
<td>$4.4 \pm 3.4 \pm 1.7$</td>
<td>$3.6 \sigma$ ($3.0 \sigma$)</td>
</tr>
</tbody>
</table>


[B. Aubert et al. (BaBar Collaboration), Phys. Rev. D 77, 012002 (2008)]
\[ \Xi_c \text{ Family: Decays to } \Lambda D \]

<table>
<thead>
<tr>
<th>Resonance</th>
<th>Mass (MeV/c^2)</th>
<th>Width (MeV)</th>
<th>Significance (\sigma)</th>
</tr>
</thead>
<tbody>
<tr>
<td>\Xi_c(3055)^0</td>
<td>3059.0 ± 0.5 ± 0.6</td>
<td>6.4 ± 2.1 ± 1.1</td>
<td>8.6</td>
</tr>
<tr>
<td>\Xi_c(3055)^+</td>
<td>3055.8 ± 0.4 ± 0.2</td>
<td>7.0 ± 1.2 ± 1.5</td>
<td>11.7</td>
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<tr>
<td>\Xi_c(3080)^+</td>
<td>3079.6 ± 0.4 ± 0.1</td>
<td>&lt; 6.3</td>
<td>4.8</td>
</tr>
</tbody>
</table>

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<tr>
<th>State</th>
<th>Decay mode</th>
<th>Mass, MeV/c²</th>
<th>Width, MeV</th>
<th>$J^P$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Xi_c'$</td>
<td>$\Xi_c^+\gamma$</td>
<td>2577.4 ± 1.2</td>
<td></td>
<td>$\frac{1}{2}^+$</td>
</tr>
<tr>
<td>$\Xi_c^0$</td>
<td>$\Xi_c^0\gamma$</td>
<td>2578.8 ± 0.5</td>
<td></td>
<td>$\frac{1}{2}^+$</td>
</tr>
<tr>
<td>$\Xi_c(2645)^+$</td>
<td>$\Xi_c^0\pi^+$</td>
<td>2645.53 ± 0.31</td>
<td>2.14 ± 0.19</td>
<td>$\frac{3}{2}^+$</td>
</tr>
<tr>
<td>$\Xi_c(2645)^0$</td>
<td>$\Xi_c^+\pi^-$</td>
<td>2646.32 ± 0.31</td>
<td>2.35 ± 0.22</td>
<td>$\frac{3}{2}^+$</td>
</tr>
<tr>
<td>$\Xi_c(2790)^+$</td>
<td>$\Xi_c^0\pi^+$</td>
<td>2792.0 ± 0.5</td>
<td>8.9 ± 1.0</td>
<td>$\frac{1}{2}^+$</td>
</tr>
<tr>
<td>$\Xi_c(2790)^0$</td>
<td>$\Xi_c^+\pi^-$</td>
<td>2792.8 ± 1.2</td>
<td>10.0 ± 1.1</td>
<td>$\frac{1}{2}^+$</td>
</tr>
<tr>
<td>$\Xi_c(2815)^+$</td>
<td>$\Xi_c^0\pi^+\pi^-, \Xi_c(2645)^0\pi^+, \Xi_c^0\pi^+$</td>
<td>2816.67 ± 0.31</td>
<td>2.43 ± 0.26</td>
<td>$\frac{3}{2}^+$</td>
</tr>
<tr>
<td>$\Xi_c(2815)^0$</td>
<td>$\Xi_c^0\pi^+\pi^-, \Xi_c(2645)^+\pi^-, \Xi_c^+\pi^-$</td>
<td>2820.22 ± 0.32</td>
<td>2.54 ± 0.25</td>
<td>$\frac{3}{2}^+$</td>
</tr>
<tr>
<td>$\Xi_c(2930)^0$</td>
<td>$\Lambda_c^+K^-$</td>
<td>2928.9±3.1$^{+3.1}_{-12.4}$</td>
<td>19.5$^{+10}_{-12}$</td>
<td></td>
</tr>
<tr>
<td>$\Xi_c(2970)^+$</td>
<td>$\Lambda_c^+K^-\pi^+, \Sigma_c^{++}K^-, \Xi_c(2645)^0\pi^+, \Xi_c^0\pi^+$</td>
<td>2969.4 ± 0.8</td>
<td>20.9$^{+2.4}_{-3.5}$</td>
<td></td>
</tr>
<tr>
<td>$\Xi_c(2970)^0$</td>
<td>$\Xi_c(2645)^+\pi^-, \Xi_c^+\pi^-$</td>
<td>2967.8 ± 0.8</td>
<td>28.1$^{+3.4}_{-4.0}$</td>
<td></td>
</tr>
<tr>
<td>$\Xi_c(3055)^+$</td>
<td>$\Sigma_c^{++}K^-, \Lambda D^+$</td>
<td>3055.9 ± 0.4</td>
<td>7.8 ± 1.9</td>
<td></td>
</tr>
<tr>
<td>$\Xi_c(3055)^0$</td>
<td>$\Lambda D^0$</td>
<td>3059.0 ± 0.8</td>
<td>6.4 ± 2.4</td>
<td></td>
</tr>
<tr>
<td>$\Xi_c(3080)^+$</td>
<td>$\Lambda_c^+K^-\pi^+, \Sigma_c^{++}K^-, \Sigma_c(2520)^{++}K^-, \Lambda D^+$</td>
<td>3077.2 ± 0.4</td>
<td>3.6 ± 1.1</td>
<td></td>
</tr>
<tr>
<td>$\Xi_c(3080)^0$</td>
<td>$\Lambda_c^+K_S^0\pi^-, \Sigma_c^0K_S^0, \Sigma_c(2520)^0K_S^0$</td>
<td>3079.9 ± 1.4</td>
<td>5.6 ± 2.2</td>
<td></td>
</tr>
</tbody>
</table>
$\Omega_c$ Family

$\Omega_c^*0 \rightarrow \Omega_c^0 \gamma$

$[70.8 \pm 1.0\, (\text{stat.}) \pm 1.1\, (\text{syst.})] \, \text{MeV}/c^2$

[B. Aubert et al. (BaBar Collaboration), Phys. Rev. Lett. 97, 232001 (2006)]

$\Delta M_{\Omega_c^0} = \left[70.7 \pm 0.9\, (\text{stat.})^+_{0.1} (\text{syst.})^-_{0.9}\right] \, \text{MeV}/c^2$

[E. Solovieva, R. Chistov et al. (Belle Collaboration), Phys. Lett. B 672, 1 (2009)]
\[\Omega_c(X)^0 \rightarrow \Xi_c^+ K^-\]

<table>
<thead>
<tr>
<th>Resonance</th>
<th>Mass (MeV)</th>
<th>(\Gamma) (MeV)</th>
<th>(N_\sigma)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\Omega_c(3000)^0)</td>
<td>3000.4 ± 0.2 ± 0.1^{+0.3}_{-0.5}</td>
<td>4.5 ± 0.6 ± 0.3</td>
<td>20.4</td>
</tr>
<tr>
<td>(\Omega_c(3050)^0)</td>
<td>3050.2 ± 0.1 ± 0.1^{+0.3}_{-0.5}</td>
<td>0.8 ± 0.2 ± 0.1</td>
<td>20.4</td>
</tr>
<tr>
<td>(\Omega_c(3066)^0)</td>
<td>3065.6 ± 0.1 ± 0.3^{+0.3}_{-0.5}</td>
<td>3.5 ± 0.4 ± 0.2</td>
<td>&lt; 1.2 MeV, 95% CL</td>
</tr>
<tr>
<td>(\Omega_c(3090)^0)</td>
<td>3090.2 ± 0.3 ± 0.5^{+0.3}_{-0.5}</td>
<td>8.7 ± 1.0 ± 0.8</td>
<td>23.9</td>
</tr>
<tr>
<td>(\Omega_c(3119)^0)</td>
<td>3119.1 ± 0.3 ± 0.9^{+0.3}_{-0.5}</td>
<td>1.1 ± 0.8 ± 0.4</td>
<td>10.4</td>
</tr>
<tr>
<td>(\Omega_c(3188)^0)</td>
<td>3188 ± 5 ± 13</td>
<td>60 ± 15 ± 11</td>
<td></td>
</tr>
</tbody>
</table>

[\text{R. Aaij et al. (LHCb Collaboration), Phys. Rev. Lett. 118, 182001 (2017)}]
$\Omega_c$ Family

$\Omega_c (X)^0 \rightarrow \Xi_c^+ K^-$

$\Xi^-\pi^+\pi^+, \Lambda K^-\pi^+\pi^+, \Xi^0\pi^+, \Sigma^0 K^-\pi^+, \Omega^-\Xi^0 K^0\pi^+$

<table>
<thead>
<tr>
<th>$\Omega_c$ Excited state</th>
<th>3000</th>
<th>3050</th>
<th>3066</th>
<th>3090</th>
<th>3119</th>
<th>3188</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield</td>
<td>$37.7 \pm 11.0$</td>
<td>$28.2 \pm 7.7$</td>
<td>$81.7 \pm 13.9$</td>
<td>$86.6 \pm 17.4$</td>
<td>$3.6 \pm 6.9$</td>
<td>$135.2 \pm 43.0$</td>
</tr>
<tr>
<td>Significance</td>
<td>$3.9\sigma$</td>
<td>$4.6\sigma$</td>
<td>$7.2\sigma$</td>
<td>$5.7\sigma$</td>
<td>$0.4\sigma$</td>
<td>$2.4\sigma$</td>
</tr>
<tr>
<td>LHCb mass</td>
<td>$3000.4 \pm 0.2 \pm 0.1$</td>
<td>$3050.2 \pm 0.1 \pm 0.1$</td>
<td>$3065.5 \pm 0.1 \pm 0.3$</td>
<td>$3090.2 \pm 0.3 \pm 0.5$</td>
<td>$3119 \pm 0.3 \pm 0.9$</td>
<td>$3188 \pm 5 \pm 13$</td>
</tr>
<tr>
<td>Belle mass (with fixed $\Gamma$)</td>
<td>$3000.7 \pm 1.0 \pm 0.2$</td>
<td>$3050.2 \pm 0.4 \pm 0.2$</td>
<td>$3064.9 \pm 0.6 \pm 0.2$</td>
<td>$3089.3 \pm 1.2 \pm 0.2$</td>
<td>$\ldots$</td>
<td>$3199 \pm 9 \pm 4$</td>
</tr>
</tbody>
</table>

[J. Yelton et al. (Belle Collaboration), Phys. Rev. D 97, 051102 (2018)]
$\Xi_{cc}^+$ Family

$\Xi_{cc}^+ \rightarrow \Lambda_c^+ K^- \pi^+$

$\Xi_{cc}^+ \rightarrow p D^+ K^-$

$M(\Lambda_c^+ K^- \pi^+)$ [GeV/c$^2$]

Events / 0.5 [MeV/c$^2$]

$M(pD^+ K^-)$

Events / 0.5 [MeV/c$^2$]

$M. Mattson et al. (SELEX Collaboration), Phys. Rev. Lett. 89, 112001 (2002)]


$$m_{\Xi_{cc}^+} = (3518.7 \pm 1.7) \text{ MeV/c}^2$$

#18
\( \Xi_{cc}^{++} \rightarrow \Lambda_{c}^{+} K^- \pi^+ \pi^+ \)

\[
\begin{align*}
\Xi_{cc}^{++} & = (3621.40 \pm 0.72 \text{[stat.]} \pm 0.27 \text{[syst.]} \pm 0.72 [\Lambda_{c}^{+}]) \text{ MeV/c}^2 \\
\Xi_{cc}^{++} - \Xi_{cc}^{++} & = (103 \pm 2) \text{ MeV/c}^2
\end{align*}
\]

Conclusions

- The $\Xi_{cc}$ state reported by LHCb is consistent with most theoretical expectations, but it is inconsistent with being an isospin partner to the $\Xi_{cc}$ state reported previously by the SELEX Collaboration.
- Recently observed excited $\Omega_c$ states present a unique opportunity to test and further improve theoretical models, that predict properties of heavy hadrons.
- More accurate $\Xi_c$ mass values is of both practical and theoretical interest, and knowing their widths can then lead to measurements of the matrix elements of their decays. These matrix elements are also applicable to other excited charm and bottom baryons.
- No direct measurements of the $J^P$ of any of the excited strange charmed baryons are available. Constraints on the quantum numbers can be inferred only from the decay pattern.
- Interesting feature is that highly excited charmed baryons can decay to a charm meson and a non-charm baryon.