

Hidden charm baryons at LHCb

Tim Burns

Swansea University

2 May 2019

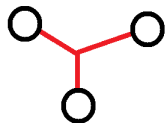
[T.B., Eur.Phys.J. A51, 152 (2015), 1509.02460]

[T.B. & E.Swanson, ongoing]

Conventional and exotic hadrons

Conventional and exotic hadrons

Baryons

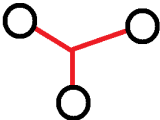


Mesons

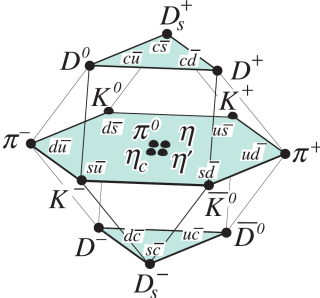
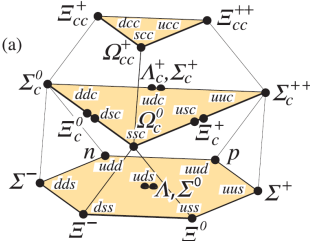


Conventional and exotic hadrons

Baryons



Mesons



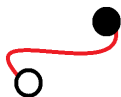
Conventional and exotic hadrons

Hybrids

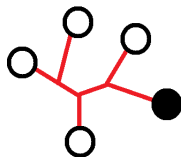
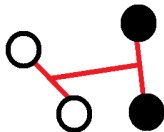


Conventional and exotic hadrons

Hybrids



Compact multiquarks

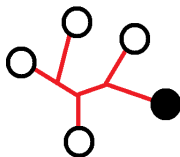
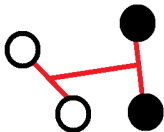


Conventional and exotic hadrons

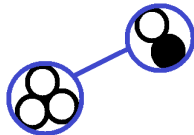
Hybrids



Compact multiquarks



Hadronic molecules

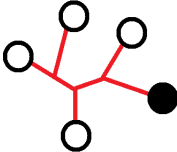
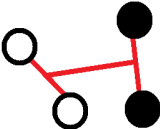


Conventional and exotic hadrons

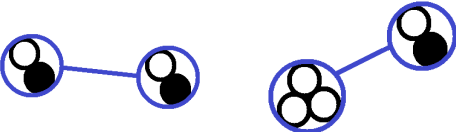
Hybrids



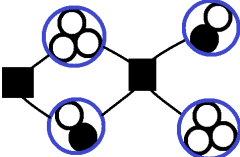
Compact multiquarks



Hadronic molecules

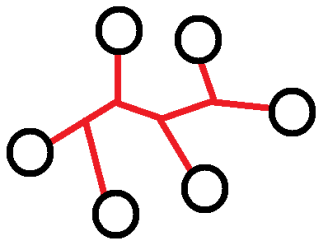


Threshold effect

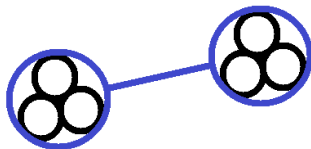


Deuteron

- ▶ 2.2 MeV below pn threshold
- ▶ $I = 0, J^P = 1^-$



vs.



- ▶ Relevant degrees of freedom are p and n
- ▶ Binding dominated by π exchange

Hadronic molecules

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$\Xi_c^{(*)} \bar{D}^{(*)}$

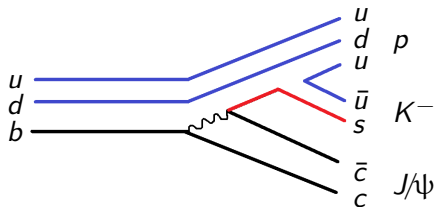
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LHCb “pentaquarks”

2015: $P_c(4380)$ and $P_c(4450)$

LHCb amplitude analysis of the three-body decay $\Lambda_b \rightarrow J/\psi p K^-$.

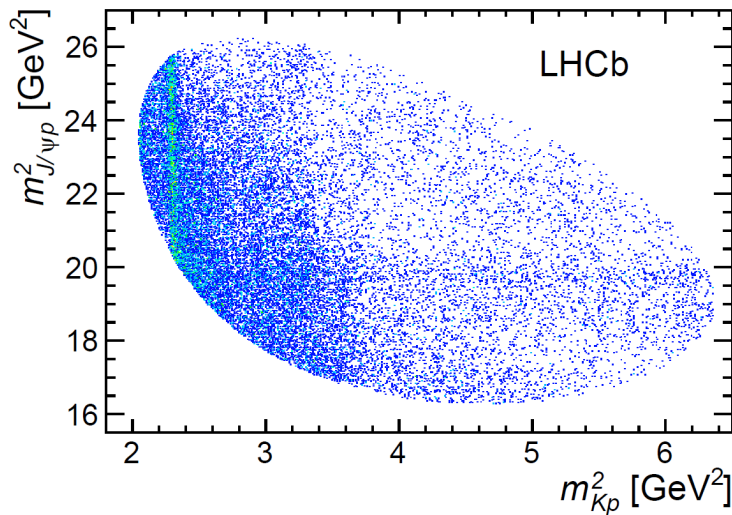
[LHCb, PRL115, 072001, 2015]



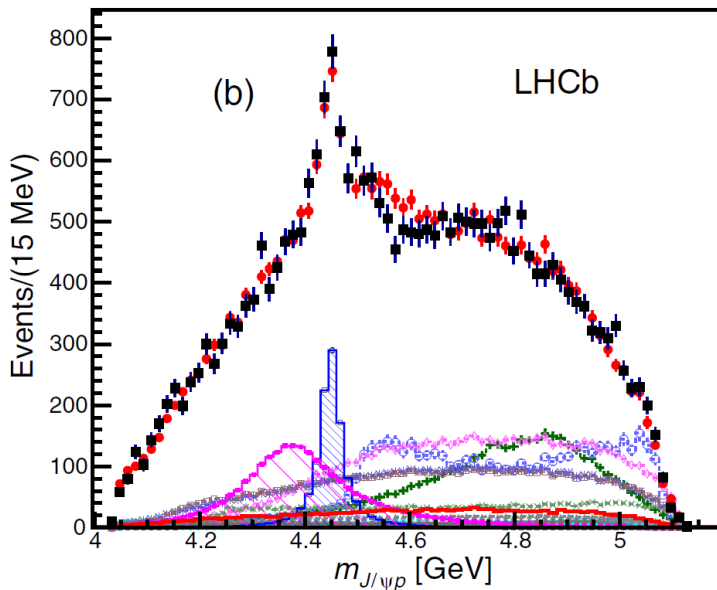
Two $J/\psi p$ states, the flavour of the proton with hidden charm ($uudc\bar{c}$).

2015: $P_c(4380)$ and $P_c(4450)$

LHCb amplitude analysis of the three-body decay $\Lambda_b \rightarrow J/\psi p K^-$.

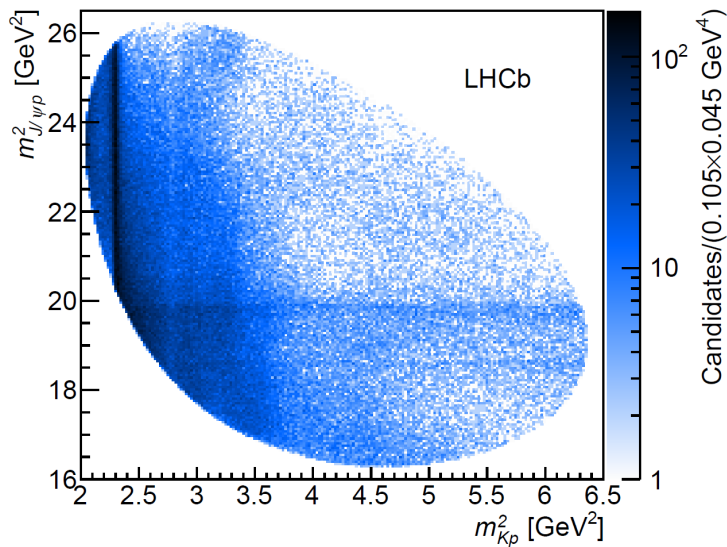


2015: $P_c(4380)$ and $P_c(4450)$

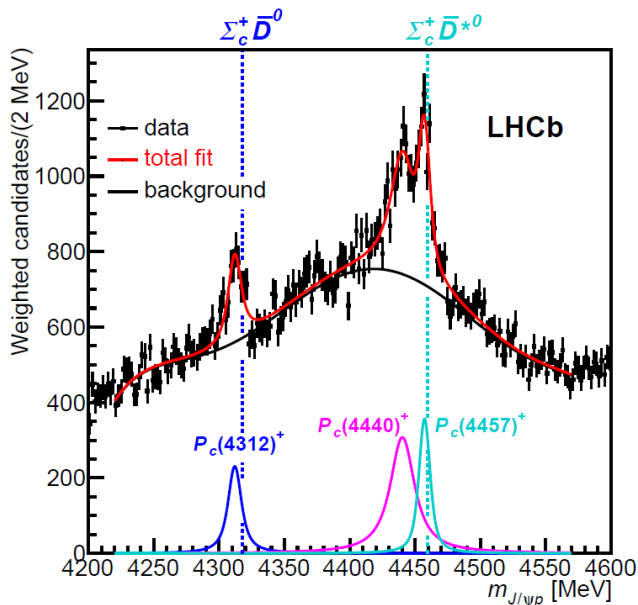


Two states with flavour of the proton, but “hidden charm”: $uudc\bar{c}$.

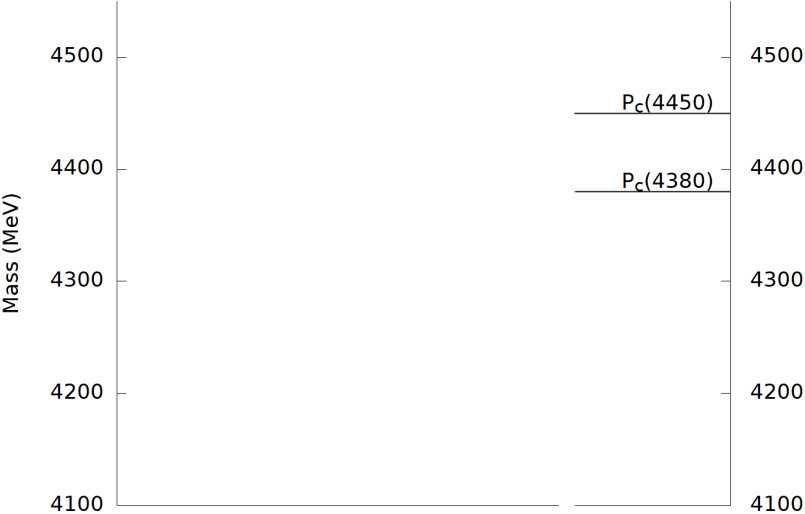
2019: $P_c(4312)$, $P_c(4440)$, $P_c(4457)$



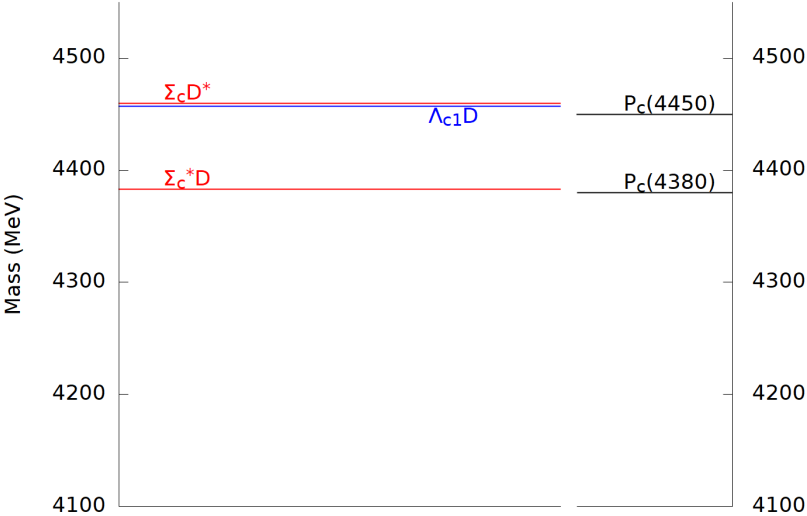
2019: $P_c(4312)$, $P_c(4440)$, $P_c(4457)$



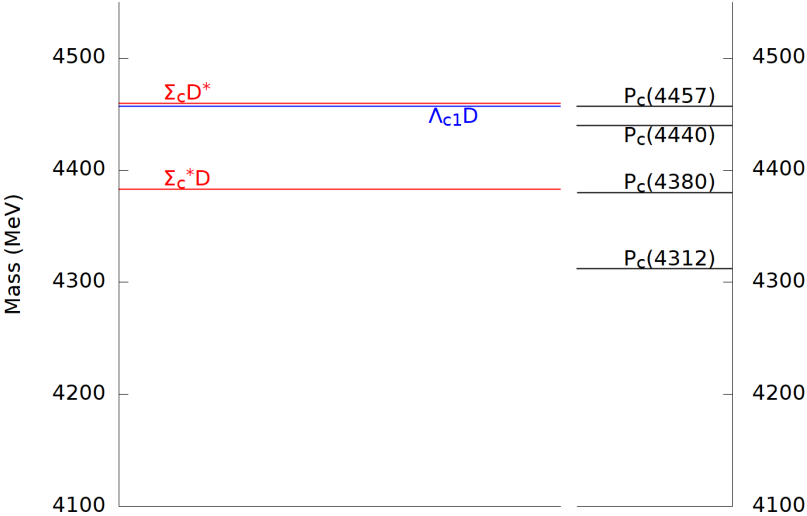
Nearby thresholds



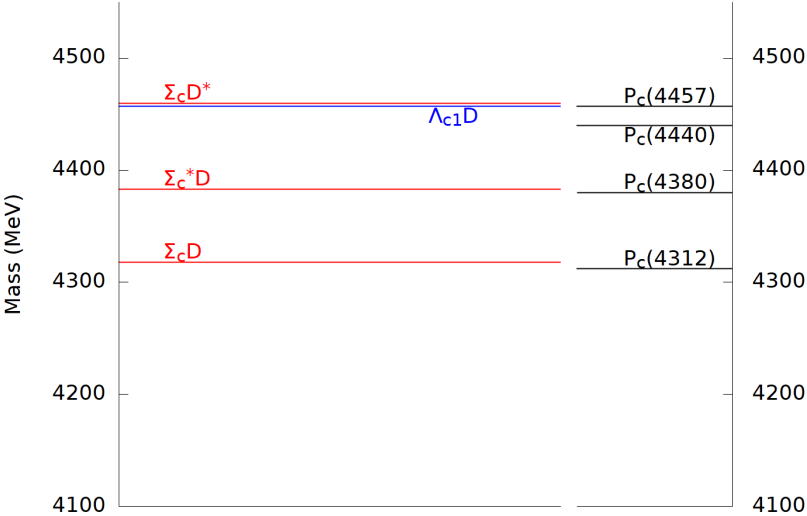
Nearby thresholds



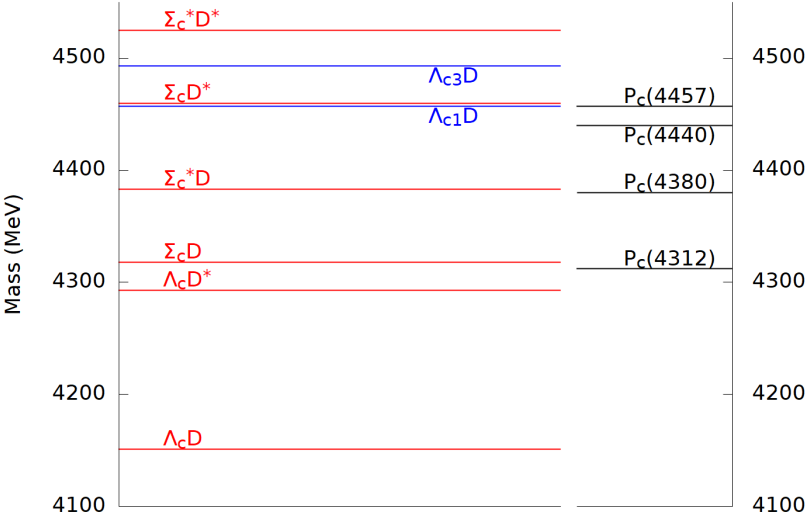
Nearby thresholds



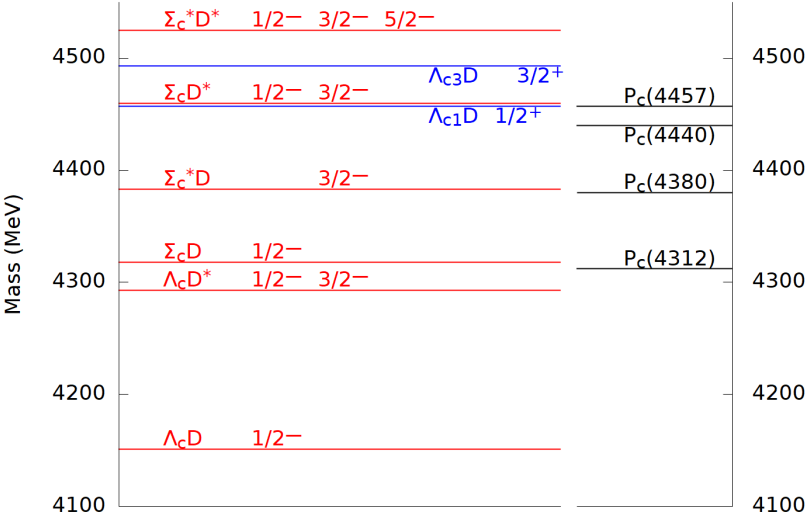
Nearby thresholds



Nearby thresholds



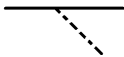
Nearby thresholds



Binding in hadronic molecules

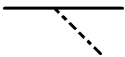
Heavy quark and chiral symmetry c.f. quark model

$$N \rightarrow N\pi$$



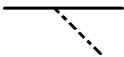
$$g_{NN\pi} \vec{\sigma} \cdot \vec{q} \vec{\tau} \cdot \vec{\pi}$$

$$\Sigma_c \rightarrow \Sigma_c \pi$$



$$g_{\Sigma_c \Sigma_c \pi} \vec{\sigma} \cdot \vec{q} \vec{T} \cdot \vec{\pi}$$

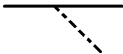
$$D^* \rightarrow D^* \pi$$




$$g_{D^* D^* \pi} \vec{\epsilon} \cdot \vec{q} \vec{\tau} \cdot \vec{\pi}$$

Heavy quark and chiral symmetry c.f. quark model

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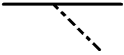


$$g_{NN\pi} \vec{\sigma} \cdot \vec{q} \vec{\tau} \cdot \vec{\pi}$$

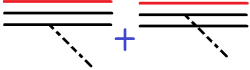


$$g_{qq\pi} \sum_{i=1}^3 \vec{\sigma}_i \cdot \vec{q} \vec{\tau}_i \cdot \vec{\pi}$$

$$\Sigma_c \rightarrow \Sigma_c \pi$$

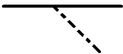


$$g_{\Sigma_c \Sigma_c \pi} \vec{\sigma} \cdot \vec{q} \vec{T} \cdot \vec{\pi}$$




$$g_{qq\pi} \sum_{i=1}^2 \vec{\sigma}_i \cdot \vec{q} \vec{\tau}_i \cdot \vec{\pi}$$

$$D^* \rightarrow D^* \pi$$



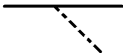
$$g_{D^* D^* \pi} \vec{\epsilon} \cdot \vec{q} \vec{\tau} \cdot \vec{\pi}$$




$$g_{qq\pi} \vec{\sigma}_1 \cdot \vec{q} \vec{\tau}_1 \cdot \vec{\pi}$$

Heavy quark and chiral symmetry c.f. quark model

$$N \rightarrow N\pi$$

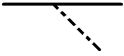


$$g_{NN\pi} \vec{\sigma} \cdot \vec{q} \vec{\tau} \cdot \vec{\pi}$$

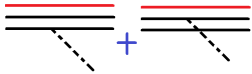


$$g_{qq\pi} \sum_{i=1}^3 \vec{\sigma}_i \cdot \vec{q} \vec{\tau}_i \cdot \vec{\pi}$$

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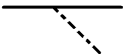


$$g_{\Sigma_c \Sigma_c \pi} \vec{\sigma} \cdot \vec{q} \vec{T} \cdot \vec{\pi}$$

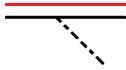


$$g_{qq\pi} \sum_{i=1}^2 \vec{\sigma}_i \cdot \vec{q} \vec{\tau}_i \cdot \vec{\pi}$$

$$D^* \rightarrow D^* \pi$$



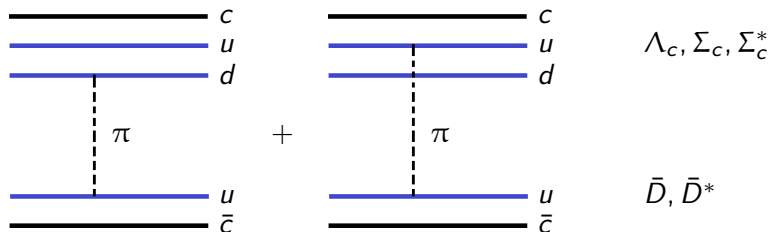
$$g_{D^* D^* \pi} \vec{\epsilon} \cdot \vec{q} \vec{\tau} \cdot \vec{\pi}$$



$$g_{qq\pi} \vec{\sigma}_1 \cdot \vec{q} \vec{\tau}_1 \cdot \vec{\pi}$$

Both approaches have the same generic form $g \vec{\Sigma} \cdot \vec{q} \vec{T} \cdot \vec{\pi}$

One-pion exchange potential



Coupled-channels, mixing angular momenta and particles, e.g.

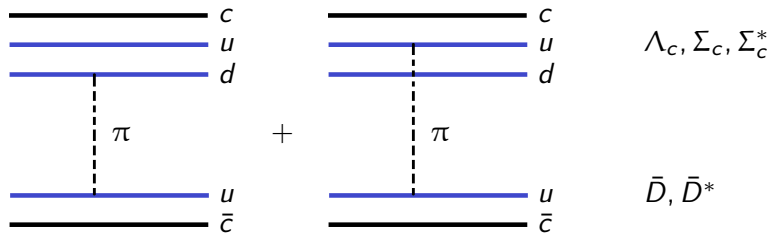
$$\Sigma_c \bar{D}^*(^2S_{1/2}) \rightarrow \Sigma_c \bar{D}^*(^4D_{1/2})$$

$$\Sigma_c \bar{D}^*(^2S_{1/2}) \rightarrow \Lambda_c \bar{D}(^2S_{1/2})$$

but first consider first elastic channels only

- ▶ $\Lambda_c \Lambda_c \pi$ vertex is forbidden (isospin)
- ▶ $\bar{D} \bar{D} \pi$ vertex is forbidden (spin-parity)

One-pion exchange potential



Coupled-channels, mixing angular momenta and particles, e.g.

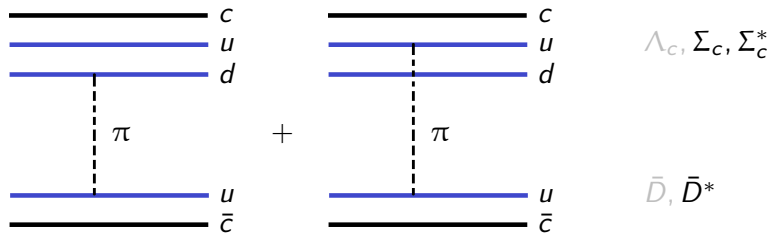
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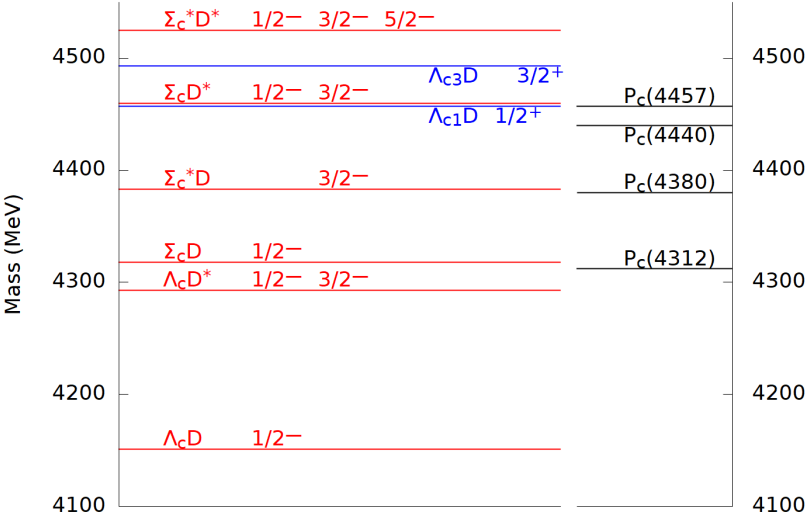
$$\Sigma_c \bar{D}^*(^2S_{1/2}) \rightarrow \Sigma_c \bar{D}^*(^4D_{1/2})$$

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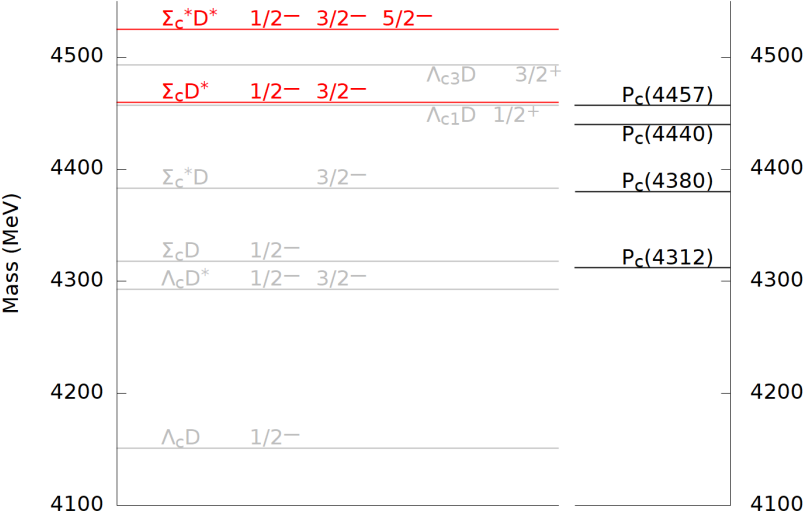
but first consider first elastic channels only

- ▶ $\Lambda_c \Lambda_c \pi$ vertex is forbidden (isospin)
- ▶ $\bar{D} \bar{D} \pi$ vertex is forbidden (spin-parity)

Restricting the spectrum



Restricting the spectrum



One-pion exchange potential

From couplings $g \vec{\Sigma} \cdot \vec{q} \vec{T} \cdot \vec{\pi}$,

$$V(\vec{r}) = [V_C(r)\vec{\Sigma}_1 \cdot \vec{\Sigma}_2 + V_T(r)S_{12}(\hat{r})] \vec{T}_1 \cdot \vec{T}_2$$

e.g. $\Sigma_c \bar{D}^*$ with $I = 1/2$, $J^P = 3/2^-$:

	$ ^4S_{3/2}\rangle$	$ ^2D_{3/2}\rangle$	$ ^4D_{3/2}\rangle$
$\langle ^4S_{3/2} $	$-\frac{8}{3}V_C$	$-\frac{8}{3}V_T$	$-\frac{16}{3}V_T$
$\langle ^2D_{3/2} $	$-\frac{8}{3}V_T$	$+\frac{16}{3}V_C$	$+\frac{8}{3}V_T$
$\langle ^4D_{3/2} $	$-\frac{16}{3}V_T$	$+\frac{8}{3}V_T$	$-\frac{8}{3}V_C$

One-pion exchange potential

From couplings $g \vec{\Sigma} \cdot \vec{q} \vec{T} \cdot \vec{\pi}$,

$$V(\vec{r}) = [V_C(r) \vec{\Sigma}_1 \cdot \vec{\Sigma}_2 + V_T(r) S_{12}(\hat{r})] \vec{T}_1 \cdot \vec{T}_2$$

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$\langle^4S_{3/2} $	$-\frac{8}{3}V_C$	$-\frac{8}{3}V_T$	$-\frac{16}{3}V_T$
$\langle^2D_{3/2} $	$-\frac{8}{3}V_T$	$+\frac{16}{3}V_C$	$+\frac{8}{3}V_T$
$\langle^4D_{3/2} $	$-\frac{16}{3}V_T$	$+\frac{8}{3}V_T$	$-\frac{8}{3}V_C$

Central and tensor potentials with form factor cutoff

One-pion exchange potential

From couplings $g \vec{\Sigma} \cdot \vec{q} \vec{T} \cdot \vec{\pi}$,

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$\langle^2D_{3/2} $	$-\frac{8}{3}V_T$	$+\frac{16}{3}V_C$	$+\frac{8}{3}V_T$
$\langle^4D_{3/2} $	$-\frac{16}{3}V_T$	$+\frac{8}{3}V_T$	$-\frac{8}{3}V_C$

Central and tensor potentials with form factor cutoff

Model-independent coefficients, fixed by HQ and isospin symmetry

One-pion exchange potential

From couplings $g \vec{\Sigma} \cdot \vec{q} \vec{T} \cdot \vec{\pi}$,

$$V(\vec{r}) = [V_C(r)\vec{\Sigma}_1 \cdot \vec{\Sigma}_2 + V_T(r)S_{12}(\hat{r})] \vec{T}_1 \cdot \vec{T}_2$$

e.g. $\Sigma_c \bar{D}^*$ with $I = 1/2$, $J^P = 3/2^-$:

	$ ^4S_{3/2}\rangle$	$ ^2D_{3/2}\rangle$	$ ^4D_{3/2}\rangle$
$\langle^4S_{3/2} $	$-\frac{8}{3}V_C$	$-\frac{8}{3}V_T$	$-\frac{16}{3}V_T$
$\langle^2D_{3/2} $	$-\frac{8}{3}V_T$	$+\frac{16}{3}V_C$	$+\frac{8}{3}V_T$
$\langle^4D_{3/2} $	$-\frac{16}{3}V_T$	$+\frac{8}{3}V_T$	$-\frac{8}{3}V_C$

Central and tensor potentials with form factor cutoff

Model-independent coefficients, fixed by HQ and isospin symmetry

Larger isospin \implies weaker potential; e.g. $V_{I=3/2} = -\frac{1}{2}V_{I=1/2}$

One-pion exchange potential

From couplings $g \vec{\Sigma} \cdot \vec{q} \vec{T} \cdot \vec{\pi}$,

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$\langle ^4D_{3/2} $	$-\frac{16}{3} V_T$	$+\frac{8}{3} V_T$	$-\frac{8}{3} V_C$

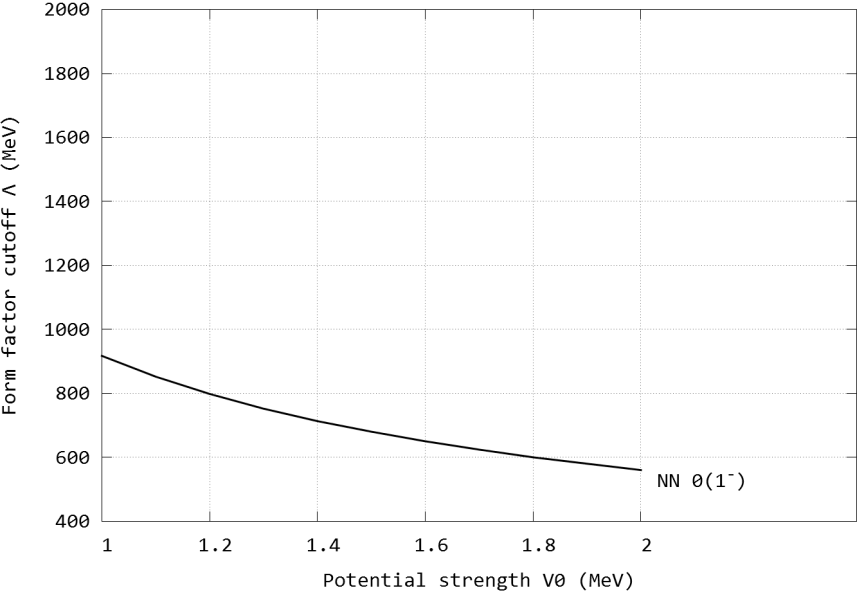
Central and tensor potentials with form factor cutoff

Model-independent coefficients, fixed by HQ and isospin symmetry

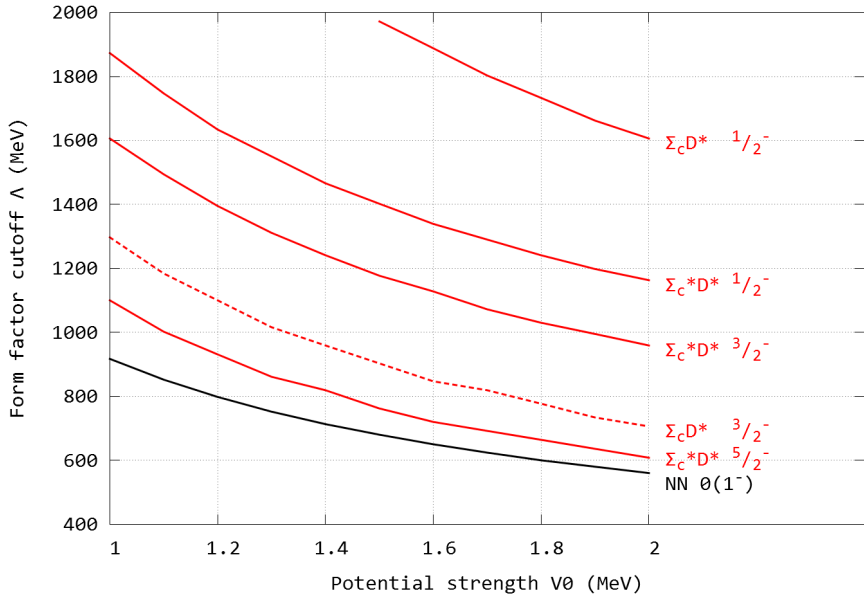
Larger isospin \implies weaker potential; e.g. $V_{I=3/2} = -\frac{1}{2} V_{I=1/2}$

Pattern of binding driven by coefficient of $V_C(r)$ in S-wave

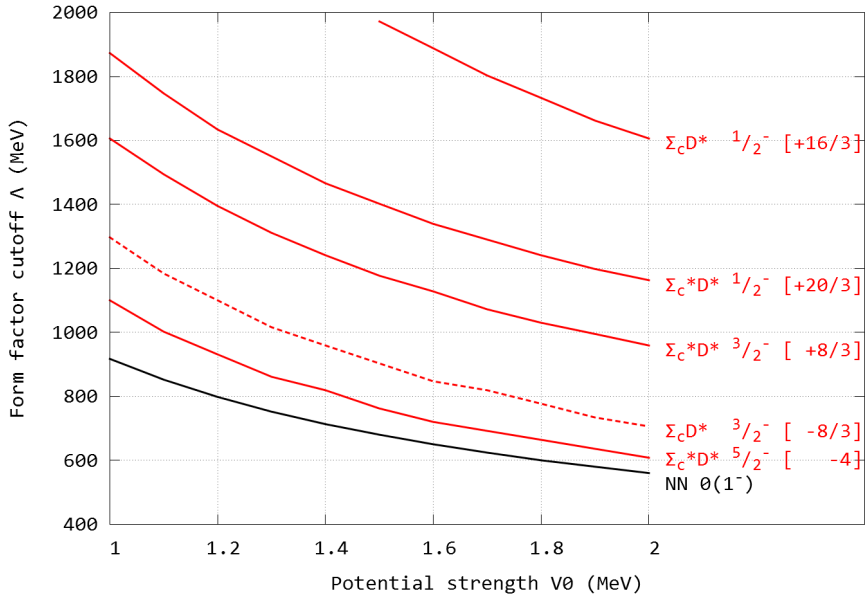
Critical form factor



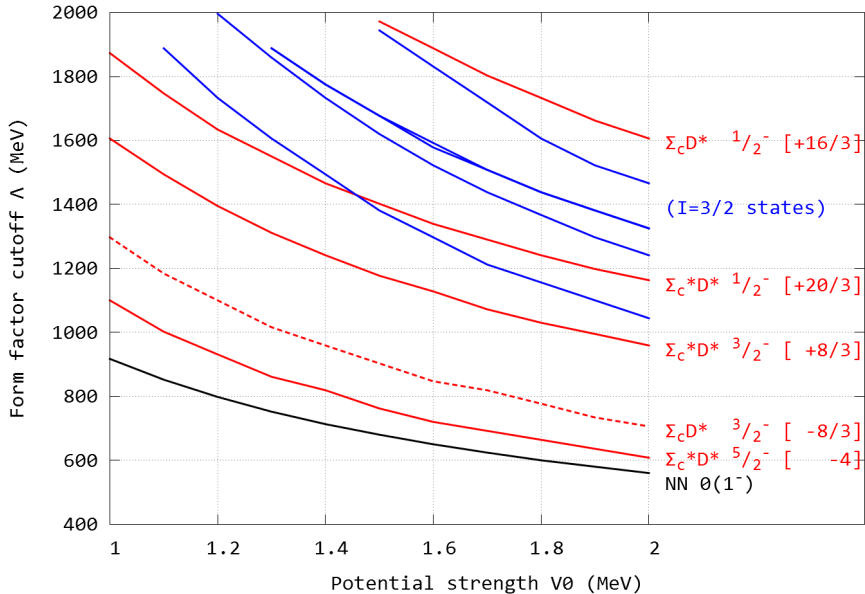
Critical form factor



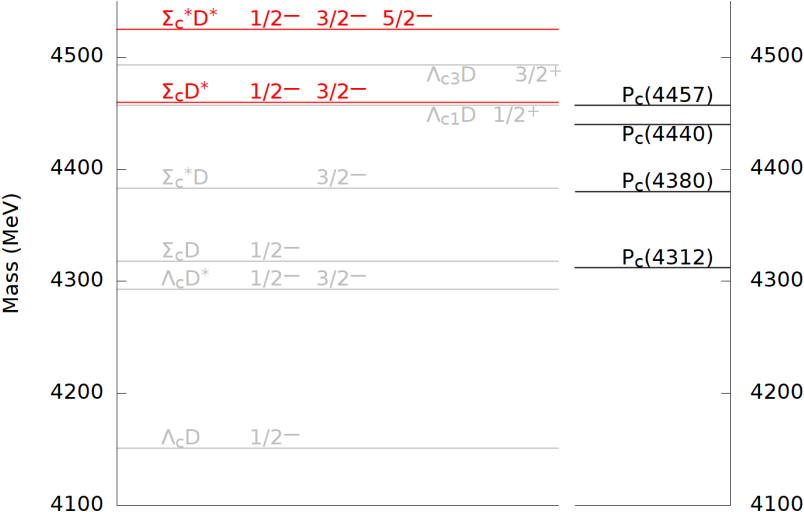
Critical form factor



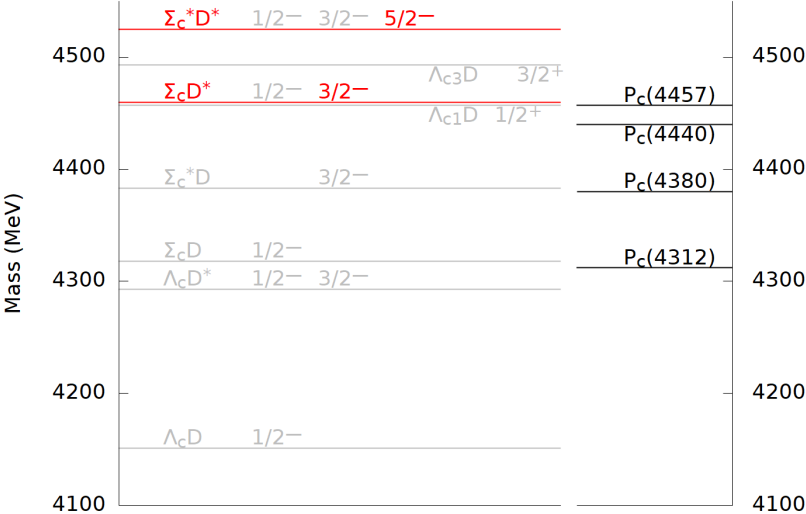
Critical form factor



Restricting the spectrum

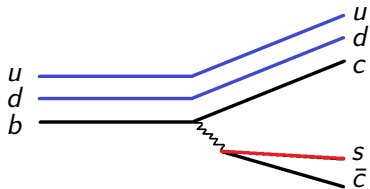


Restricting the spectrum

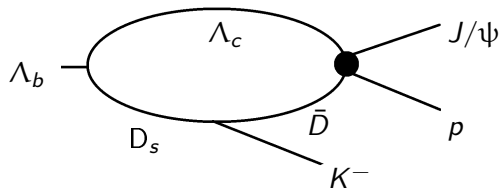
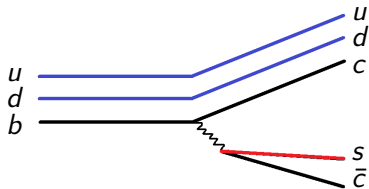


Production
and
particle coupled-channels

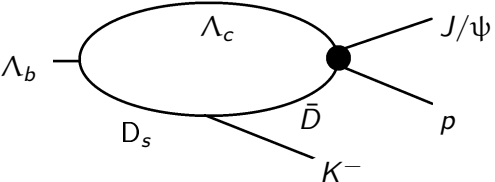
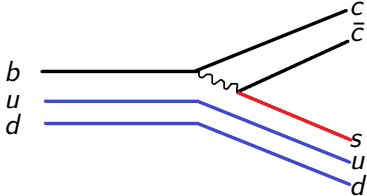
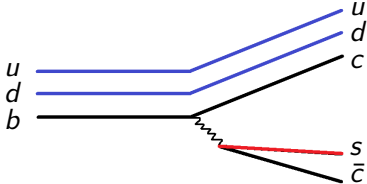
Production favours Λ_c -flavoured components



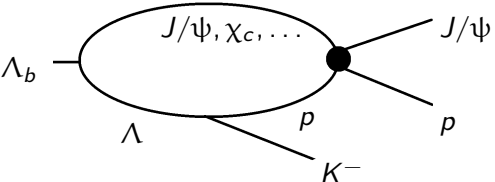
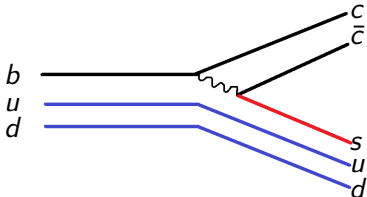
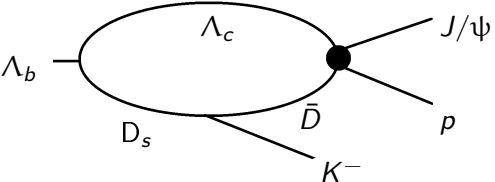
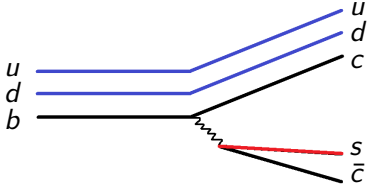
Production favours Λ_c -flavoured components



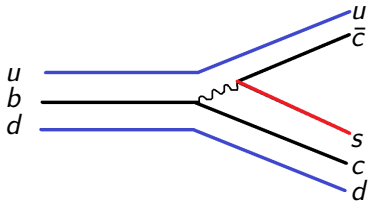
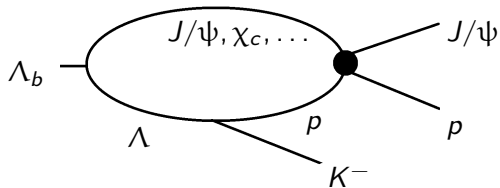
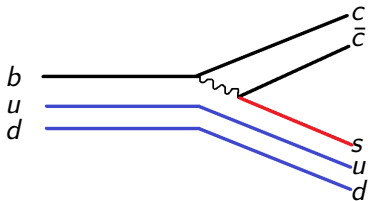
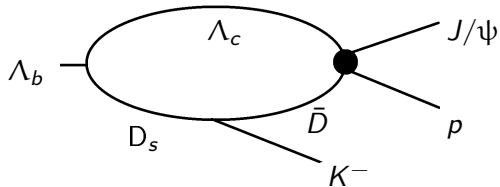
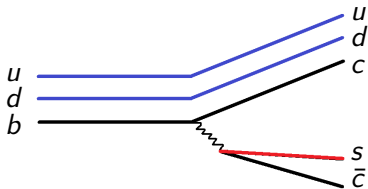
Production favours Λ_c -flavoured components



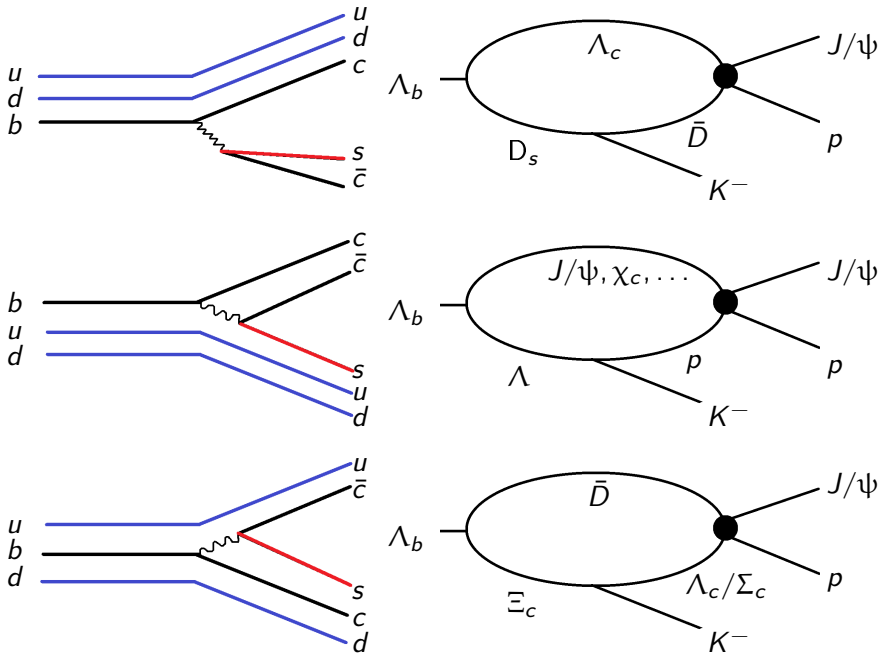
Production favours Λ_c -flavoured components



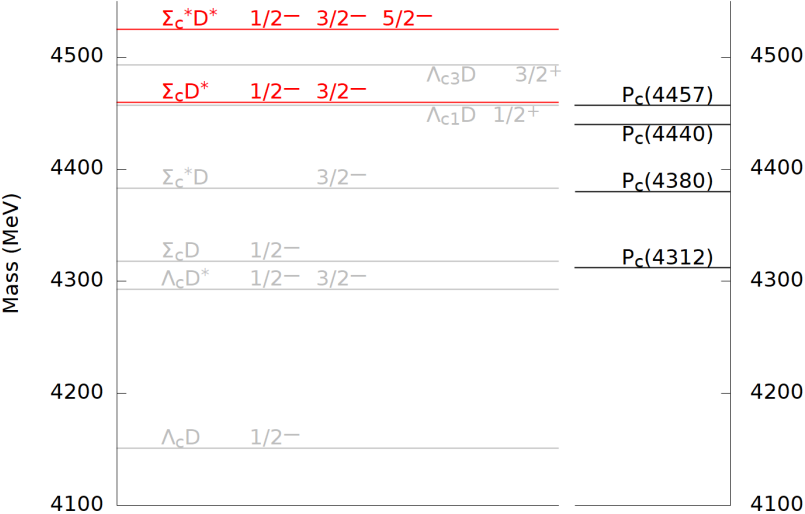
Production favours Λ_c -flavoured components



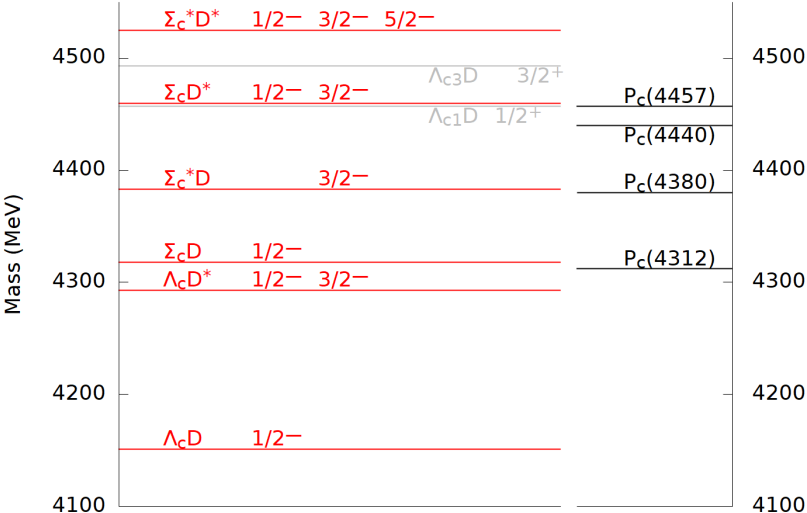
Production favours Λ_c -flavoured components



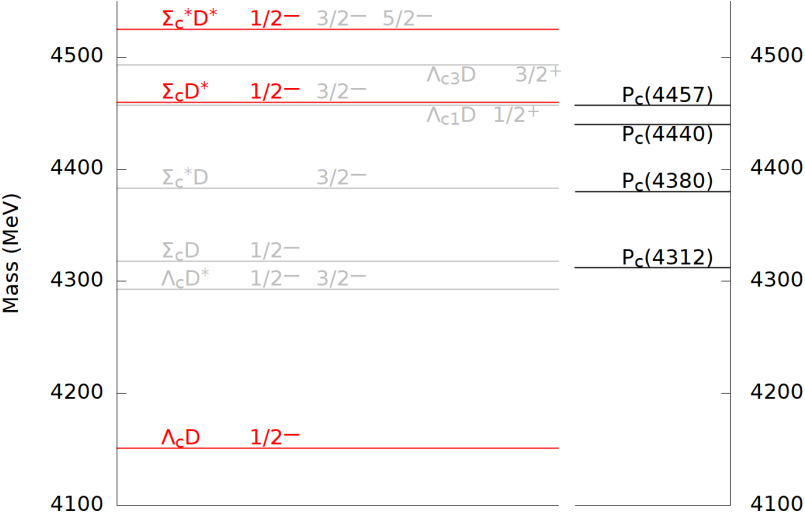
Including particle coupled-channel effects



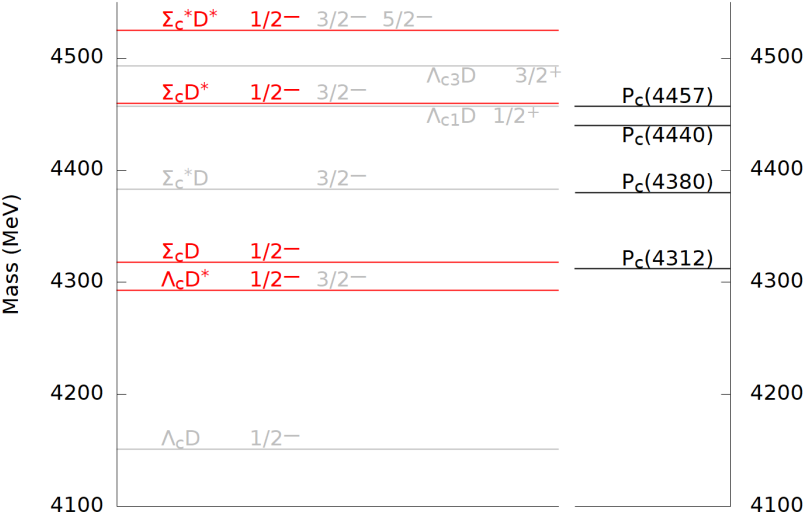
Including particle coupled-channel effects



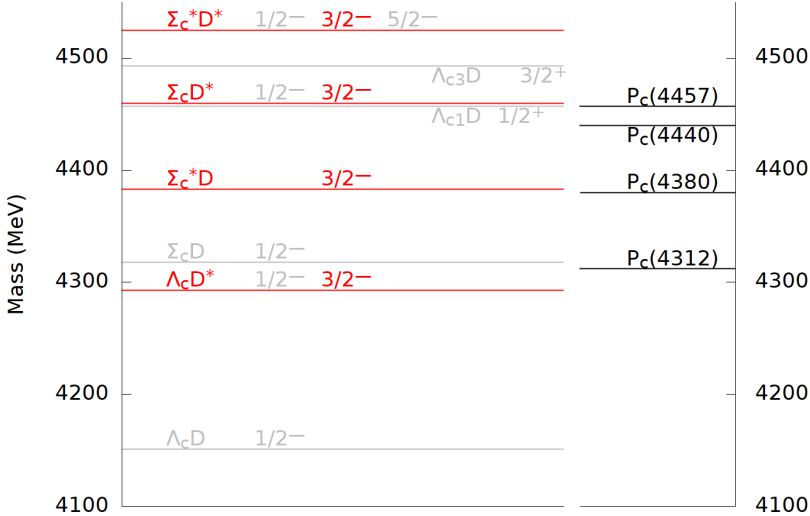
Including particle coupled-channel effects



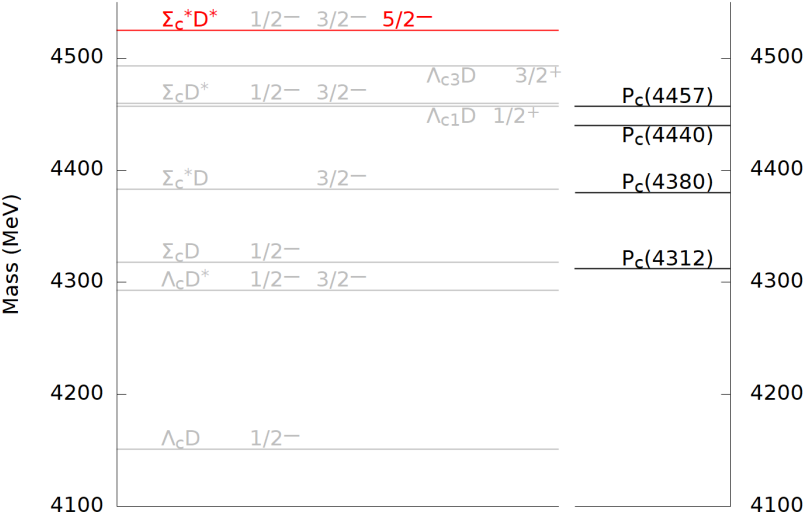
Including particle coupled-channel effects



Including particle coupled-channel effects

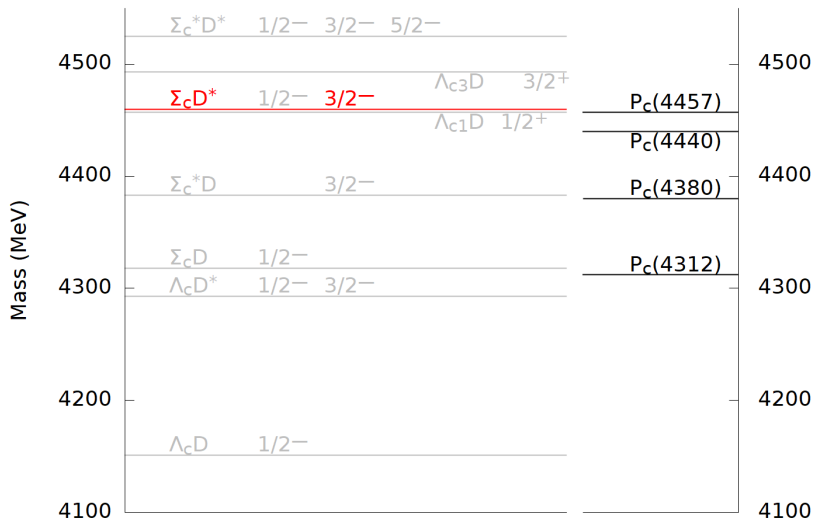


Including particle coupled-channel effects

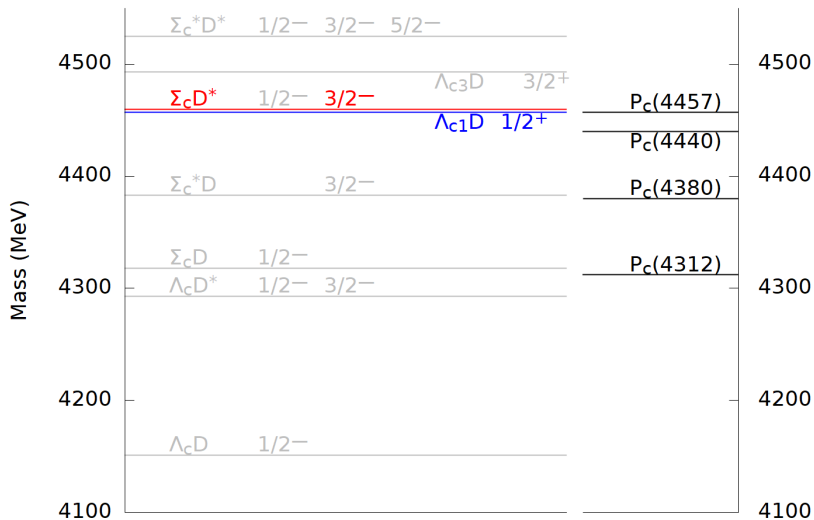


The new doublet of states

The role of $\Lambda_{c1}\bar{D}$



The role of $\Lambda_{c1}\bar{D}$



The role of $\Lambda_{c1} \bar{D}$

$$\Sigma_c \bar{D}^* \rightarrow \Sigma_c \bar{D}^* \quad V(\vec{r}) = [V_C(r) \vec{\Sigma}_1 \cdot \vec{\Sigma}_2 + V_T(r) S_{12}(\hat{r})] \vec{T}_1 \cdot \vec{T}_2$$

$$\Lambda_{c1} \bar{D} \rightarrow \Sigma_c \bar{D}^* \quad V(\vec{r}) = V_V(r) \vec{\Sigma}_2 \cdot \hat{r} \vec{T}_1 \cdot \vec{T}_2$$

Access to opposite parity states with S-wave components:

	$\Sigma_c \bar{D}^*$	$\Lambda_{c1} \bar{D}$	
$1/2^-$	${}^2S_{1/2}$ ${}^4D_{1/2}$		unbound
$3/2^-$	${}^4S_{3/2}$ ${}^2D_{3/2}$ ${}^4D_{3/2}$		$P_c(4457)$

The role of $\Lambda_{c1}\bar{D}$

$$\Sigma_c\bar{D}^* \rightarrow \Sigma_c\bar{D}^* \quad V(\vec{r}) = [V_C(r)\vec{\Sigma}_1 \cdot \vec{\Sigma}_2 + V_T(r)S_{12}(\hat{r})] \vec{T}_1 \cdot \vec{T}_2$$

$$\Lambda_{c1}\bar{D} \rightarrow \Sigma_c\bar{D}^* \quad V(\vec{r}) = V_V(r)\vec{\Sigma}_2 \cdot \hat{r} \vec{T}_1 \cdot \vec{T}_2$$

Access to opposite parity states with S-wave components:

	$\Sigma_c\bar{D}^*$	$\Lambda_{c1}\bar{D}$	
$1/2^-$	$^2S_{1/2}$ $^4D_{1/2}$		unbound
$3/2^-$	$^4S_{3/2}$ $^2D_{3/2}$ $^4D_{3/2}$		$P_c(4457)$
$1/2^+$		$^2S_{1/2}$	

The role of $\Lambda_{c1} \bar{D}$

$$\Sigma_c \bar{D}^* \rightarrow \Sigma_c \bar{D}^* \quad V(\vec{r}) = [V_C(r) \vec{\Sigma}_1 \cdot \vec{\Sigma}_2 + V_T(r) S_{12}(\hat{r})] \vec{T}_1 \cdot \vec{T}_2$$

$$\Lambda_{c1} \bar{D} \rightarrow \Sigma_c \bar{D}^* \quad V(\vec{r}) = V_V(r) \vec{\Sigma}_2 \cdot \hat{r} \vec{T}_1 \cdot \vec{T}_2$$

Access to opposite parity states with S-wave components:

	$\Sigma_c \bar{D}^*$	$\Lambda_{c1} \bar{D}$	
$1/2^-$	${}^2S_{1/2} \quad {}^4D_{1/2}$	${}^2P_{1/2}$	unbound
$3/2^-$	${}^4S_{3/2} \quad {}^2D_{3/2} \quad {}^4D_{3/2}$	${}^2P_{3/2}$	$P_c(4457)$
$1/2^+$	${}^2P_{1/2} \quad {}^4P_{1/2}$	${}^2S_{1/2}$	

The role of $\Lambda_{c1} \bar{D}$

$$\Sigma_c \bar{D}^* \rightarrow \Sigma_c \bar{D}^* \quad V(\vec{r}) = [V_C(r) \vec{\Sigma}_1 \cdot \vec{\Sigma}_2 + V_T(r) S_{12}(\hat{r})] \vec{T}_1 \cdot \vec{T}_2$$

$$\Lambda_{c1} \bar{D} \rightarrow \Sigma_c \bar{D}^* \quad V(\vec{r}) = V_V(r) \vec{\Sigma}_2 \cdot \hat{r} \vec{T}_1 \cdot \vec{T}_2$$

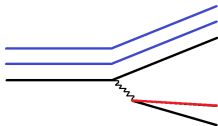
Access to opposite parity states with S-wave components:

	$\Sigma_c \bar{D}^*$	$\Lambda_{c1} \bar{D}$	
$1/2^-$	${}^2S_{1/2}$ ${}^4D_{1/2}$	${}^2P_{1/2}$	unbound
$3/2^-$	${}^4S_{3/2}$ ${}^2D_{3/2}$ ${}^4D_{3/2}$	${}^2P_{3/2}$	$P_c(4457)$
$1/2^+$	${}^2P_{1/2}$ ${}^4P_{1/2}$	${}^2S_{1/2}$	$P_c(4440)$

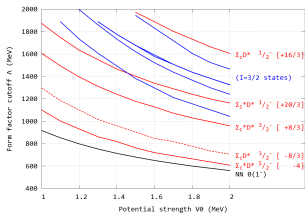
Conclusions



Patterns of binding are readily understood in terms of model-independent numerical factors



Quark model and Lagrangians based on HQ and chiral symmetry give the same OPE potential.



Production favours Λ_c channels, implying coupled channel effects for observed states, and supporting the absence of $5/2^-$ state

Conclusions

A restricted spectrum emerges, with unambiguous J^P quantum numbers which can be tested in experiment:

$$\begin{array}{lll} P_c(4457) & 3/2^- & \Sigma_c \bar{D}^* (+\Lambda_{c1} \bar{D}) \\ P_c(4440) & 1/2^+ & \Lambda_{c1} \bar{D} (+\Sigma_c \bar{D}^*) \\ P_c(4380) & 3/2^- & \Sigma_c^* \bar{D} (+\dots) \\ P_c(4312) & 1/2^- & \Sigma_c \bar{D} + \Lambda_c D^* \end{array}$$

States have mixed isospin:

$$|P_c\rangle = \cos \phi |\frac{1}{2}, \frac{1}{2}\rangle + \sin \phi |\frac{3}{2}, \frac{1}{2}\rangle$$

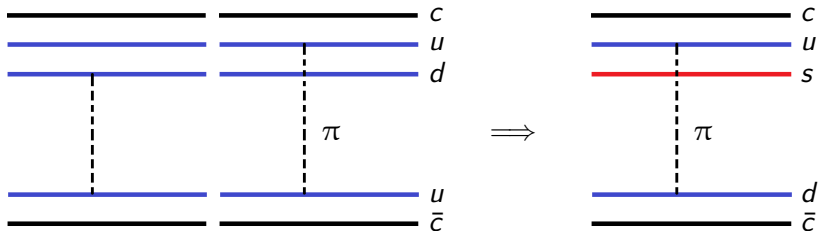
but $|\frac{3}{2}, \frac{3}{2}\rangle$ partners not expected.

Compact pentaquark scenarios have model-dependent masses, and many more states, with all possible I and J^P .

More molecules, and isospin mixing

$\Xi_c^* \bar{D}^*$ molecules

$$\begin{aligned} \Lambda_c &= ((ud)_0 c)_{1/2} & \implies & \Xi_c = ((us)_0 c)_{1/2} \\ \Sigma_c &= ((ud)_1 c)_{1/2} & \implies & \Xi'_c = ((us)_1 c)_{1/2} \\ \Sigma_c^* &= ((ud)_1 c)_{3/2} & \implies & \Xi_c^* = ((us)_1 c)_{3/2} \end{aligned}$$



The potential matrices (central + tensor) are directly related.

Predict loosely bound $0(5/2^-)$ $\Xi_c^* \bar{D}^*$ state, observable in $\Lambda_b \rightarrow J/\psi \Lambda \eta$, and $\Xi_b \rightarrow J/\psi \Lambda K^-$ (LHCb run II).

Isospin mixing: $P_c(4380)$ and $P_c(4457)$

$$uudc\bar{c} = \begin{cases} (udc)(u\bar{c}) = \Sigma_c^+ \bar{D}^0 \\ (uuc)(d\bar{c}) = \Sigma_c^{++} D^- \end{cases}$$

Isospin-conserving interactions give $|I, I_3\rangle$ eigenstates,

$$\begin{pmatrix} |\frac{1}{2}, \frac{1}{2}\rangle \\ |\frac{3}{2}, \frac{1}{2}\rangle \end{pmatrix} = \begin{pmatrix} -\sqrt{\frac{1}{3}} & \sqrt{\frac{2}{3}} \\ \sqrt{\frac{2}{3}} & \sqrt{\frac{1}{3}} \end{pmatrix} \begin{pmatrix} |\Sigma_c^+ \bar{D}^0\rangle \\ |\Sigma_c^{++} D^-\rangle \end{pmatrix}$$

but only if the masses $\Sigma_c^+ = \Sigma_c^{++}$ and $\bar{D}^0 = D^-$.

Otherwise, isospin is not a good quantum number.

Isospin mixing: $P_c(4380)$ and $P_c(4457)$

$$\begin{aligned} P_c(4380) &= 4380 \pm 8 \pm 29 & P_c(4457) &= 4457.3 \pm 0.6^{+4.1}_{-1.7} \\ \Sigma_c^{*+} \bar{D}^0 &= 4382.3 \pm 2.4 & \Sigma_c^+ \bar{D}^{*0} &= 4459.9 \pm 0.5 \\ \Sigma_c^{*++} D^- &= 4387.5 \pm 0.7 & \Sigma_c^{++} D^{*-} &= 4464.24 \pm 0.23 \end{aligned}$$

The P_c states have mixed isospin:

$$|P_c\rangle = \cos \phi \left| \frac{1}{2}, \frac{1}{2} \right\rangle + \sin \phi \left| \frac{3}{2}, \frac{1}{2} \right\rangle$$

They should decay also into $J/\psi \Delta^+$ and $\eta_c \Delta^+$, with weights:

$$\begin{aligned} J/\psi p : J/\psi \Delta^+ : \eta_c \Delta^+ &= 2 \cos^2 \phi : 5 \sin^2 \phi : 3 \sin^2 \phi & [P_c(4380)] \\ J/\psi p : J/\psi \Delta^+ : \eta_c \Delta^+ &= \cos^2 \phi : 10 \sin^2 \phi : 6 \sin^2 \phi & [P_c(4457)] \end{aligned}$$

Isospin mixing: predicted $5/2^-$ states

$$\Sigma_c^* \bar{D}^* \quad 1/2(5/2^-)$$

$$\Sigma_c^{*+} \bar{D}^{*0} = 4524.4 \pm 2.4$$

$$\Sigma_c^{*++} D^{*-} = 4528.2 \pm 0.7$$

Mixed isospin:

$$|P\rangle = \cos \phi \left| \frac{1}{2}, \frac{1}{2} \right\rangle + \sin \phi \left| \frac{3}{2}, \frac{1}{2} \right\rangle$$

Decays:

→ $J/\psi p$: D-wave, spin flip

Reason for absence at LHCb?

→ $J/\psi \Delta$: S-wave, spin cons.

⇒ $I = 3/2$ decay enhanced.

Isospin mixing: predicted $5/2^-$ states

$$\Sigma_c^* \bar{D}^* 1/2(5/2^-)$$

$$\Xi_c^* \bar{D}^* 0(5/2^-)$$

$$\Sigma_c^{*+} \bar{D}^{*0} = 4524.4 \pm 2.4$$

$$\Xi_c^{*0} \bar{D}^{*0} = 4652.9 \pm 0.6$$

$$\Sigma_c^{*++} D^{*-} = 4528.2 \pm 0.7$$

$$\Xi_c^{*+} D^{*-} = 4656.2 \pm 0.7$$

Mixed isospin:

$$|P\rangle = \cos \phi |\frac{1}{2}, \frac{1}{2}\rangle + \sin \phi |\frac{3}{2}, \frac{1}{2}\rangle$$

Mixed isospin:

$$|P\rangle = \cos \phi |0, 0\rangle + \sin \phi |1, 0\rangle$$

Decays:

$\rightarrow J/\psi p$: D-wave, spin flip

Reason for absence at LHCb?

Decays:

$\rightarrow J/\psi \Lambda$: D-wave, spin flip

e.g. $\Lambda_b^0 \rightarrow J/\psi \Lambda \eta, J/\psi \Lambda \phi$

$\rightarrow J/\psi \Delta$: S-wave, spin cons.

$\implies I = 3/2$ decay enhanced.

$\rightarrow J/\psi \Sigma^*$: S-wave, spin cons.

$\implies I = 1$ decay enhanced.