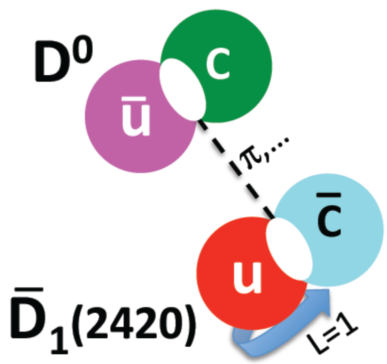
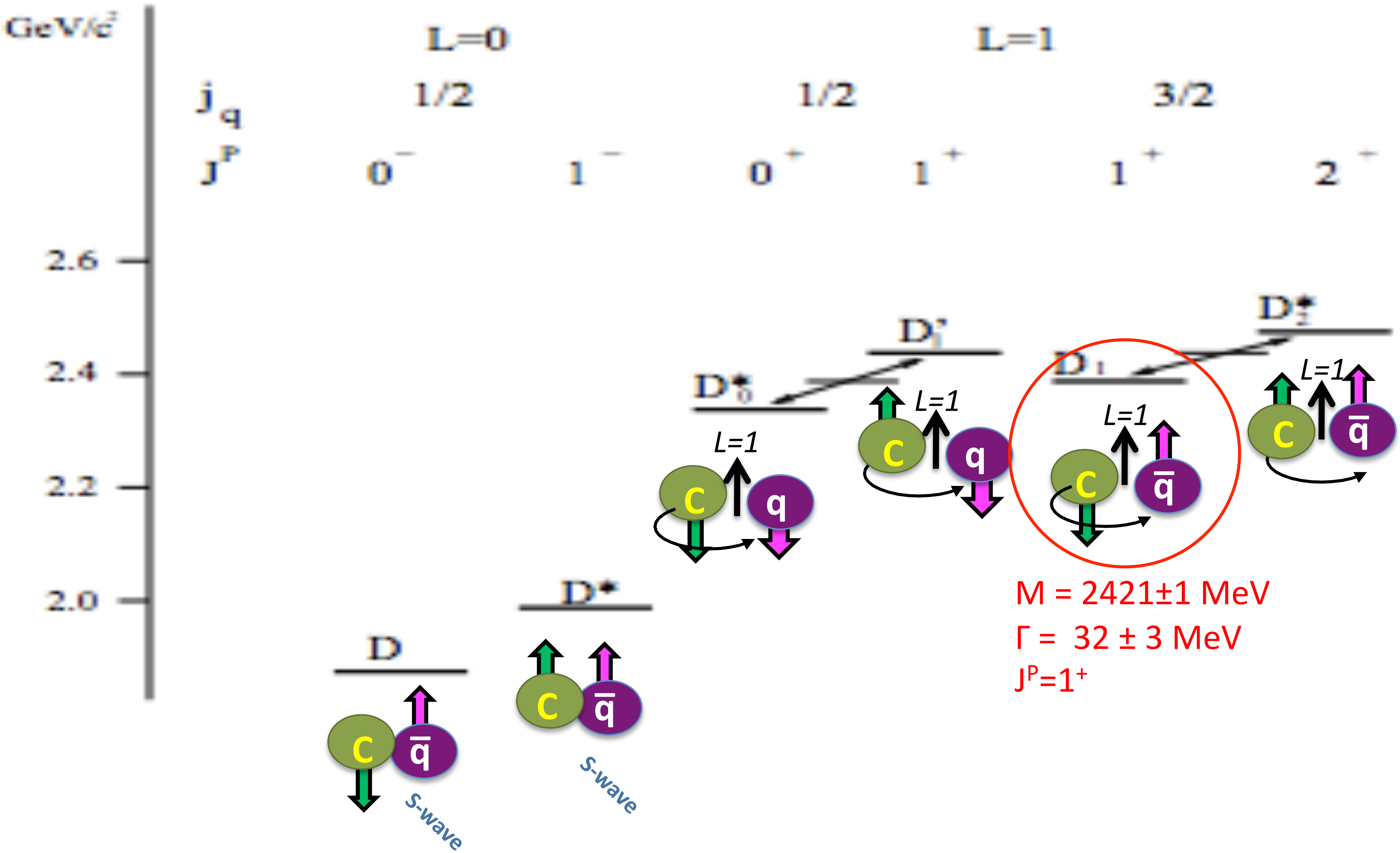
Probing the $D_1(2420)\bar{D}$ content of the Y(4260)



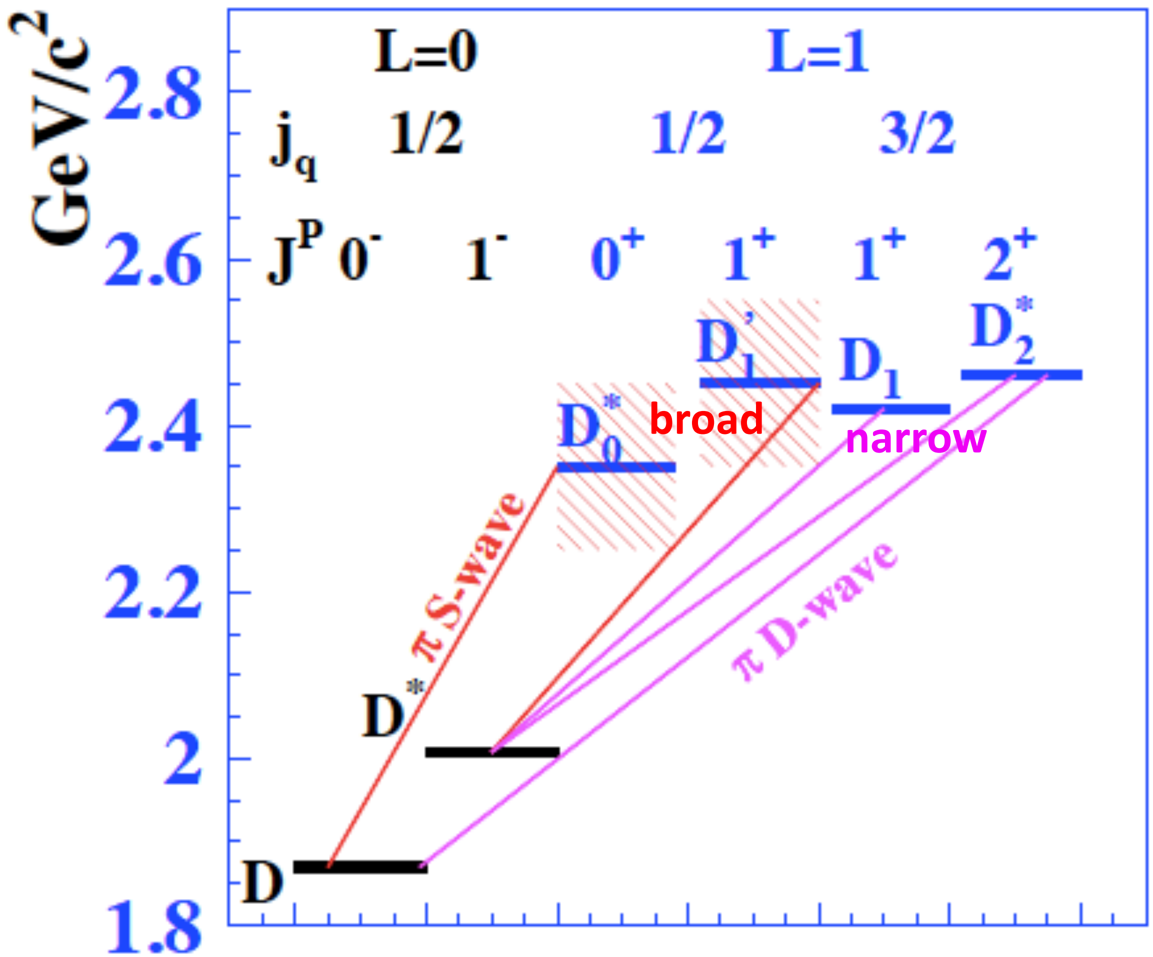
Stephen Lars Olsen

What is the $D_1(2420)$?

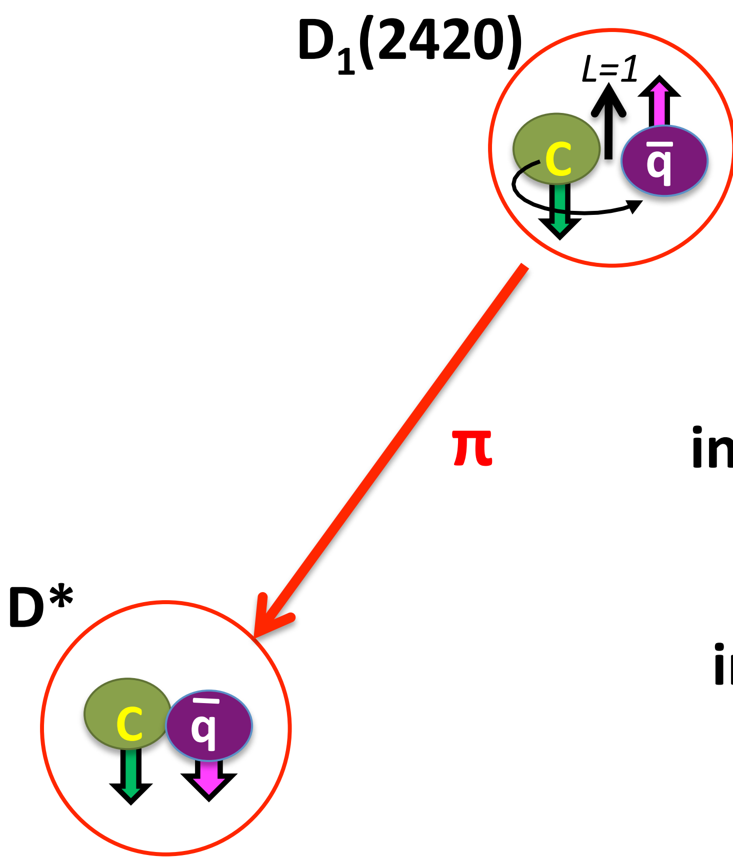
-- the low-mass D meson spectrum --



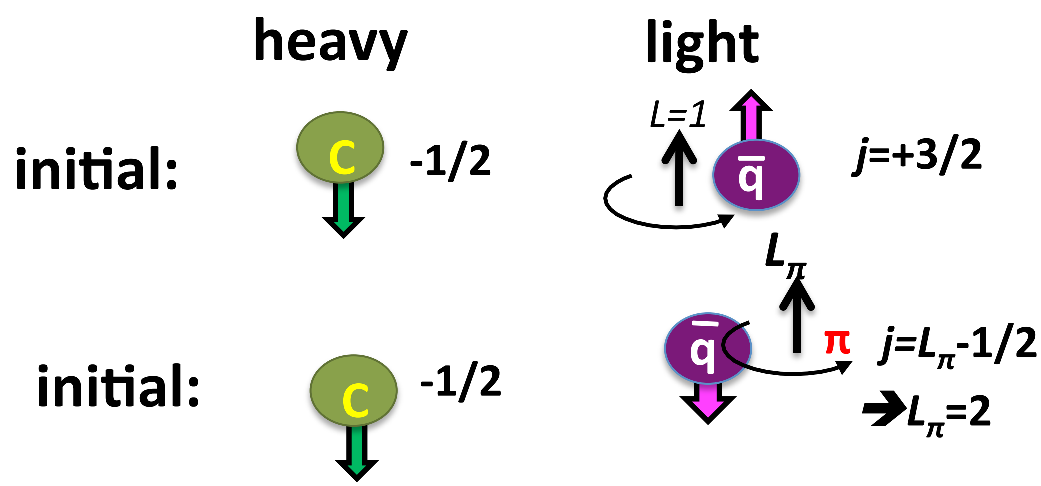
Theory: $D_1(2420) \rightarrow D^*\pi$ decay produces a D-wave $D^*\pi$ system



heavy quark spin symmetry

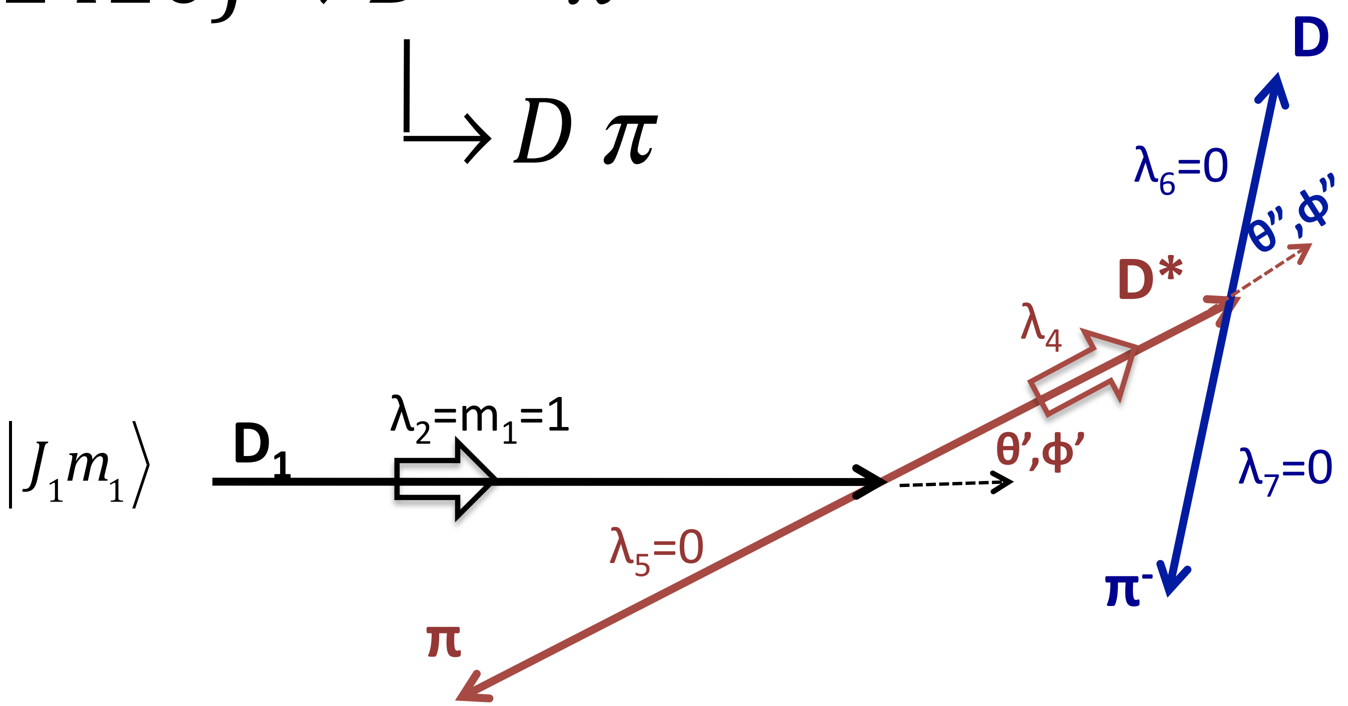


the light quark and heavy quark angular momentum are separately conserved



can this be tested?

$$D_1(2420) \rightarrow D^* + \pi$$
$$\quad \hookrightarrow D\,\pi$$



$$A(\theta',\phi',\theta'',\phi'',m_1,0,0,0\ ) = \frac{3}{4\pi}\sum_{\lambda_4=+1,0,-1} B_{\lambda_4 0} D^{1*}_{1\lambda_4}(\theta',\phi') C_{00} D^{1*}_{\lambda_4 0}(\theta'',\phi'')$$

Evaluate: $C_{00}\sum_{\lambda_4=+1,0,-1} B_{\lambda_4 0} D^{1*}_{1\lambda_4}(\theta',\phi') D^{1*}_{\lambda_4 0}(\theta'',\phi'')$

$B_{-10}=B_{10};\ B_{00}\neq 0$

$D^{1*}_{1\pm1}(\theta',\phi')=e^{i\phi'}\left(e^{\mp i\phi'}(1\pm\cos\theta')/2\right)$

$D^{1*}_{10}(\theta',\phi')=-\frac{1}{\sqrt{2}}e^{i\phi'}\sin\theta'$

$D^{1*}_{\pm10}(\theta'',\phi'')=e^{\pm i\phi''}d^{1}_{\pm10}(\theta'')$

$=\mp\frac{1}{\sqrt{2}}e^{\pm i\phi''}\sin\theta''$

$D^{1}_{00}(\theta'')=d^{1}_{00}(\theta'')=\cos\theta''$

$$C_{00}\sum_{\lambda_4=+1,0,-1} B_{\lambda_4 0} D^{1*}_{1\lambda_4}(\theta',\phi') D^{1*}_{\lambda_2 0}(\theta'',\phi'')$$

$$=\frac{-1}{2\sqrt{2}}C_{00}e^{i\phi'}\left(B_{10}\sin\theta''(e^{-i\phi'}(1+\cos\theta')e^{i\phi''}-e^{i\phi'}(1-\cos\theta')e^{-i\phi''})+2B_{00}\sin\theta'\cos\theta''\right)$$

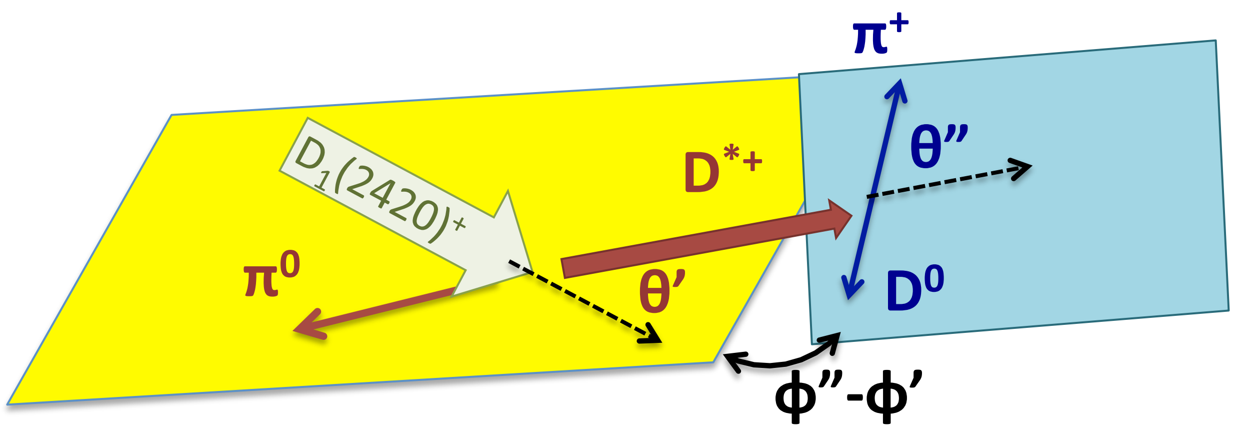
two independent helicity amplitudes

$$\left.\frac{d\Gamma}{d(\theta',\theta'',(\phi''-\phi'))}\right|_{m_{D_1}=+1} \propto \left|\sum_{\lambda_4=+1,0,-1} B_{\lambda_4 0} D^{1*}_{1\lambda_4}(\theta',\phi') D^{1*}_{\lambda_4 0}(\theta'',\phi'')\right|^2$$

$$\propto |B_{10}|^2 \frac{\sin^2\theta''}{4}(1+\cos^2\theta'+\sin^2\theta'\cos 2(\phi''-\phi'))$$

$$+|B_{00}|^2 \frac{\cos^2\theta''\sin^2\theta'}{2}$$

$$+\mathcal{R}e(B^*_{10}B_{00})\sin\theta'\cos\theta'\sin\theta''\cos\theta''\cos(\phi''-\phi')$$



Integrate over θ' and ϕ"-ϕ'

$$\frac{d\Gamma}{d\cos\theta''} = \int\left(\left.\frac{d\Gamma}{d(\theta',\theta'',(\phi''-\phi'))}\right|_{m_{D_1}=+1} \right) d\cos\theta' d(\phi''-\phi')$$

$$\propto \left|B_{10}\right|^2 \sin^2\theta'' + \left|B_{00}\right| \cos^2\theta''$$

CLEOII Phys. Lett. B331, 236 (1994) says that you get the same

relation for m_1=0. Let's assume that is true.

$$\frac{d\Gamma}{d\cos\theta''} \propto \left|B_{10}\right|^2 \sin^2\theta'' + \left|B_{00}\right| \cos^2\theta''$$ for all m values

Helicity and Partial-Wave amplitudes

$$B_{10} = \frac{S}{\sqrt{3}} + \frac{D}{\sqrt{6}}$$

$$B_{00} = \frac{S}{\sqrt{3}} - \sqrt{\frac{2}{3}} D$$

$$\Rightarrow \text{ if } S = 0: \quad B_{00} = -2B_{10}$$

$$\left|B_{00}\right|^2 = 4\left|B_{10}\right|^2$$

$$\Rightarrow \text{ if } D = 0: \quad B_{00} = B_{10}$$

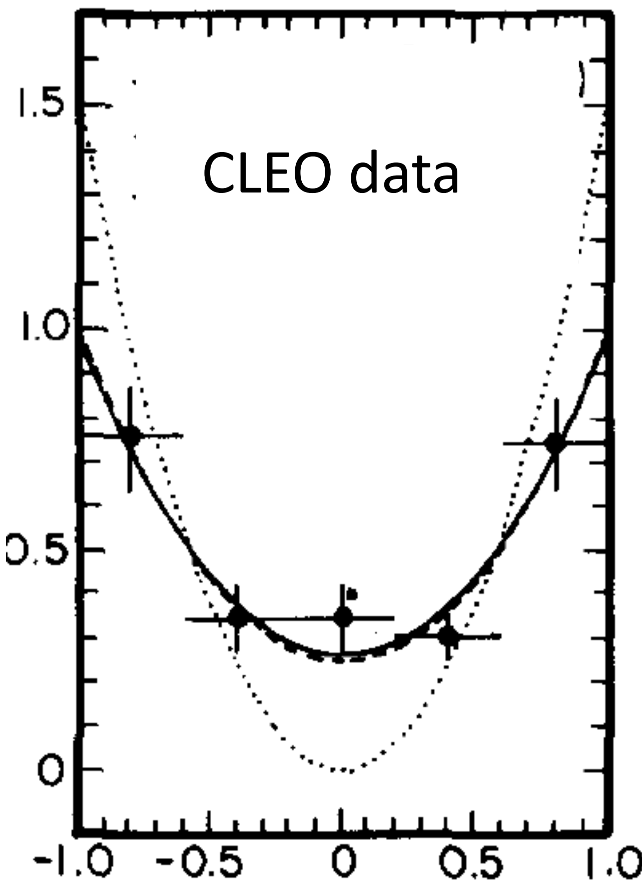
$$\left|B_{00}\right|^2 = \left|B_{10}\right|^2$$

if S=0 (*i.e.* $D_1(2420) \rightarrow D^*\pi$ is all D-wave)

$$\frac{d\Gamma}{d\cos\theta''} \propto \left|B_{10}\right|^2 (\sin^2\theta'' + 4\cos^2\theta'') = \left|B_{10}\right|^2 (1 + 3\cos^2\theta'')$$

if S=0 (*i.e.* $D_1(2420) \rightarrow D^*\pi$ is all D-wave)

$$\frac{d\Gamma}{d\cos\theta''} \propto |B_{10}|^2 (\sin^2\theta'' + 4\cos^2\theta'') = |B_{10}|^2 (1+3\cos^2\theta'')$$



$\cos^2\theta''$

$1+3\cos^2\theta''$

data agrees well with D-wave

CLEOII Phys. Lett. B331, 236 (1994)

Full amplitude

$$e^+e^- \to Y(4260) \to D_1(2420)\bar{D}$$

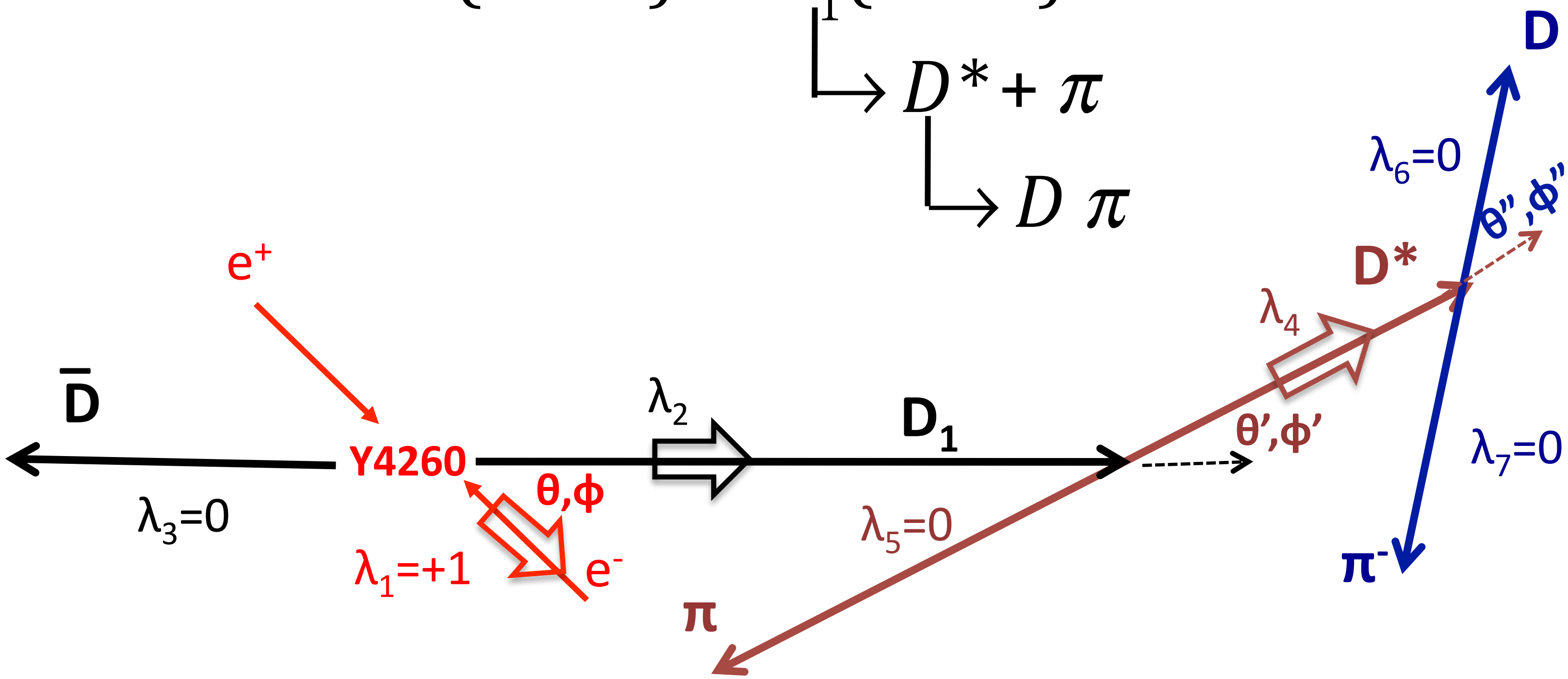
$$\hookrightarrow D^* + \pi$$

$$\hookrightarrow D\ \pi$$

$$e^+e^- \to Y(4260) \to D_1(2420)\bar{D}$$

$$\quad\quad\quad\quad\quad\quad\quad \hookrightarrow D^* + \pi$$

$$\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad \hookrightarrow D\,\pi$$



$$A(\theta,\phi,\theta',\phi',\theta'',\phi'',m_1=1,0,0,0\;)=$$

$$\frac{3\sqrt{3}}{8\pi^{3/2}} \sum_{\lambda_2,\lambda_4=+1,0,-1} A_{\lambda_2 0} D^{1*}_{1\lambda_2} B_{\lambda_4 0} D^{1*}_{\lambda_2\lambda_4}(\theta',\phi') C_{00} D^{1*}_{\lambda_4 0}(\theta'',\phi'')$$

Parity: $A_{-10}=+A_{10}$; $A_{00}\neq 0$ and $B_{-10}=+B_{10}$; $B_{00}\neq 0$

possible constraints

if $D_1(2420) \to D^* \pi$ is pure D-wave: $B_{00} = -2B_{10}$

$Y(4260) \to D_1(2420)\bar{D} \to D^* \pi$ is at threshold: D-wave $\approx$ 0: $A_{00} = A_{10}$