Measurement of Semileptonic B-Decays into Orbitally Excited D-Mesons with the BABAR Detector

$$B \to D^{**}\ell\nu$$

Armin Hauke

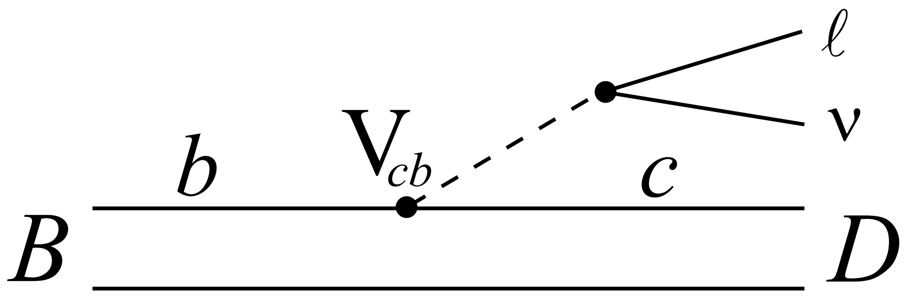
- Motivation : D^{**} from semileptonic B-decays
- D^{**} mesons – states, decays and reconstruction
- Extraction of the branching ratios
- Results and systematic studies
- Outlook

UNIVERSITÄT DORTMUND

BABAR™

bmb+f - Förderschwerpunkt BABAR Großgeräte der physikalischen Grundlagenforschung

Motivation



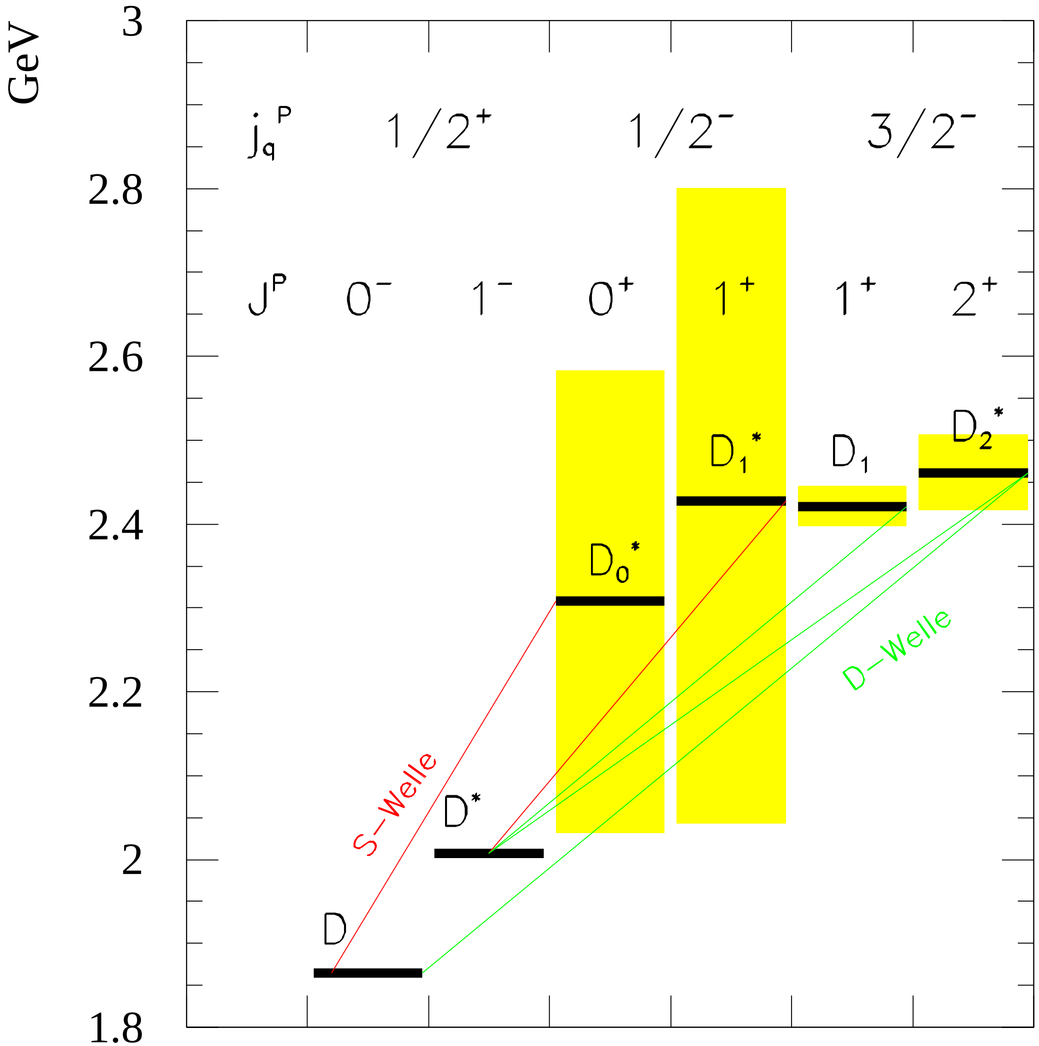
Semileptonic decays because

- undetectable neutrino vs. clean signature and absence of strong FSI
- meson description by HQET
- combination of exclusive and inclusive analyses
- most direct access on V_{xb}

D^{**} because

- needed for exclusiv (background) and inclusiv (completenes) analyses
- $\Gamma_{B\to D^{**}\ell\nu}/\Gamma_{b\to c\ell\nu} \approx 20\%$
- little is known on
  - different states of D^{**} and
  - their decays

Spectroscopy of D mesons – what's a D^{**}?



spin-parity of light quark

spin-parity of meson

Telling from the widths a possible mixing of the two 1^+-states seems to be small

Throughout this talk D^{**} denotes the (narrow) orbitally excited mesons, also known as D_J.

Subsequent decays of the narrow D^{**}

D_1^0	$\xrightarrow{33\%}$	$D^{*0}\pi^0$	$\xrightarrow{62\%}$	$D^0\pi^0\pi^0$	20%		
D_1^0	$\xrightarrow{66\%}$	$D^{*\pm}\pi^\mp$	$\xrightarrow{68\%}$	$D^0\pi^\pm\pi^\mp$	45%	$\triangleleft$	*CLEO:* $\mathcal{B}_{SL} = (5.6 \pm 1.6) \times 10^{-3}$
D_2^{*0}	$\xrightarrow{11\%}$	$D^{*0}\pi^0$	$\xrightarrow{62\%}$	$D^0\pi^0\pi^0$	7%		
D_2^{*0}	$\xrightarrow{22\%}$	$D^{*\pm}\pi^\mp$	$\xrightarrow{68\%}$	$D^0\pi^\pm\pi^\mp$	15%	$\triangleleft$	*CLEO:* $\mathcal{B}_{SL} < 8 \times 10^{-3}$
D_2^{*0}	$\xrightarrow{22\%}$			$D^0\pi^0$	22%		
D_2^{*0}	$\xrightarrow{44\%}$			$D^\pm\pi^\mp$	44%	$\triangleleft$	
$D_1^\pm$	$\xrightarrow{66\%}$	$D^{*0}\pi^\pm$	$\xrightarrow{62\%}$	$D^0\pi^0\pi^\pm$	41%	$\triangleleft$	
$D_1^\pm$	$\xrightarrow{33\%}$	$D^{*\pm}\pi^0$	$\xrightarrow{68\%}$	$D^0\pi^\pm\pi^0$	22%		
$D_2^{*\pm}$	$\xrightarrow{22\%}$	$D^{*0}\pi^\pm$	$\xrightarrow{62\%}$	$D^0\pi^0\pi^\pm$	14%	$\triangleleft$	
$D_2^{*\pm}$	$\xrightarrow{11\%}$	$D^{*\pm}\pi^0$	$\xrightarrow{68\%}$	$D^0\pi^\pm\pi^0$	7%		
$D_2^{*\pm}$	$\xrightarrow{44\%}$			$D^0\pi^\pm$	44%	$\triangleleft$	
$D_2^{*\pm}$	$\xrightarrow{22\%}$			$D^\pm\pi^0$	22%		

Goal of this analysis:

measurement of **all** narrow D^{**}-states in semileptonic B-decays

The Babar-Detector at the PEP-II Storage Ring

Signal-signature:

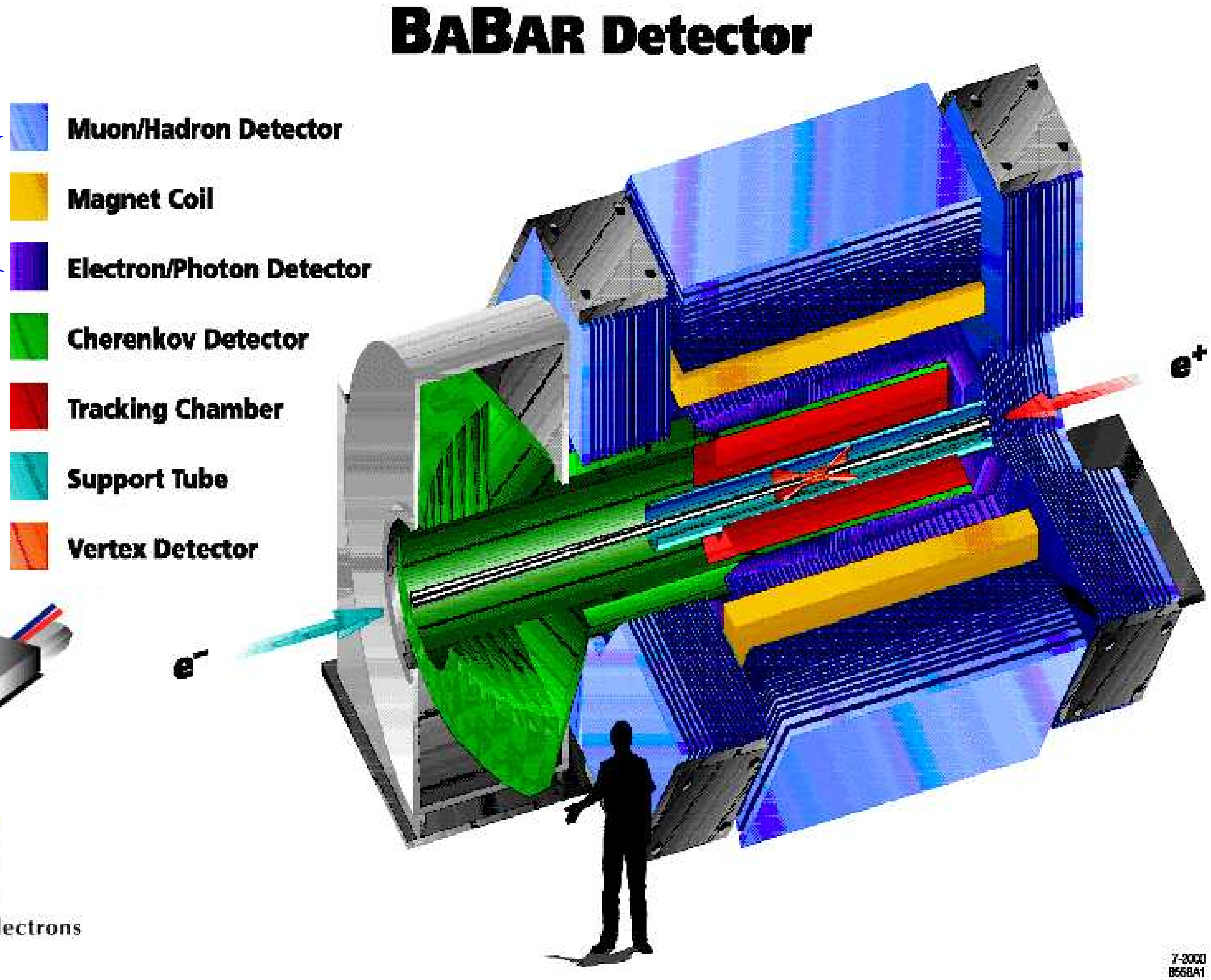
$K^-\pi^+\pi^{-/0}\pi^+\ell^-$

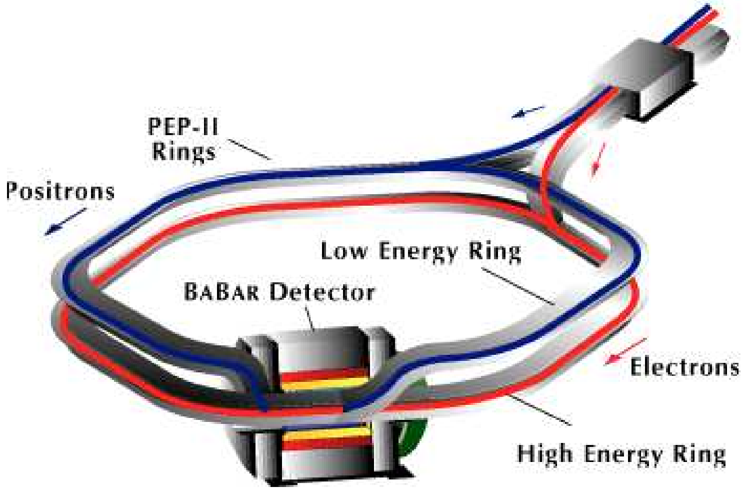
ℓ

$\pi^0 \to \gamma\gamma$

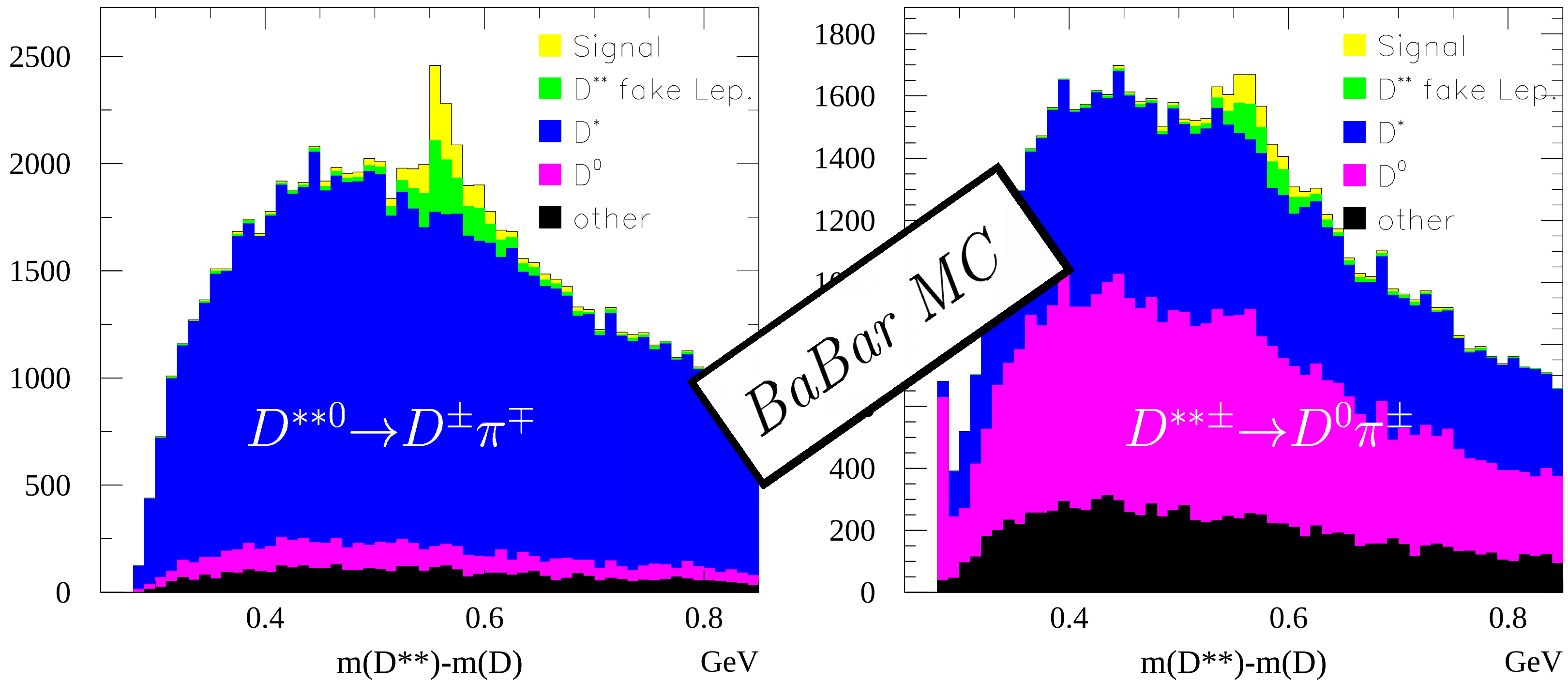
K^-

π^+





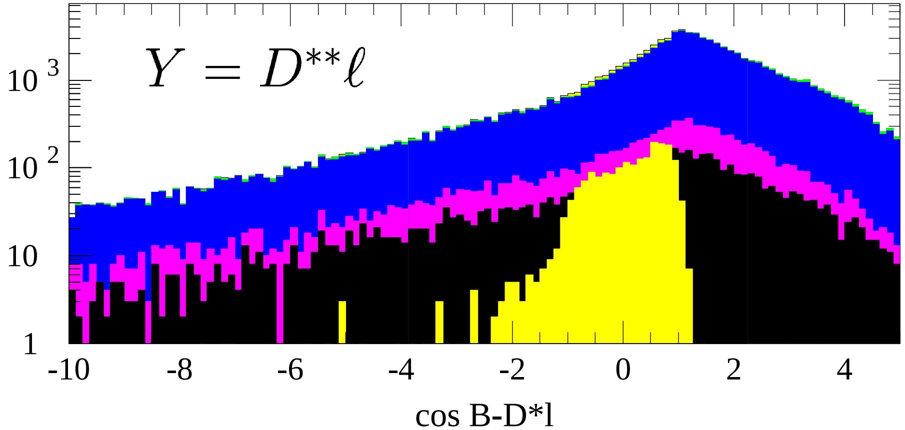
Spectra of Mass-Difference



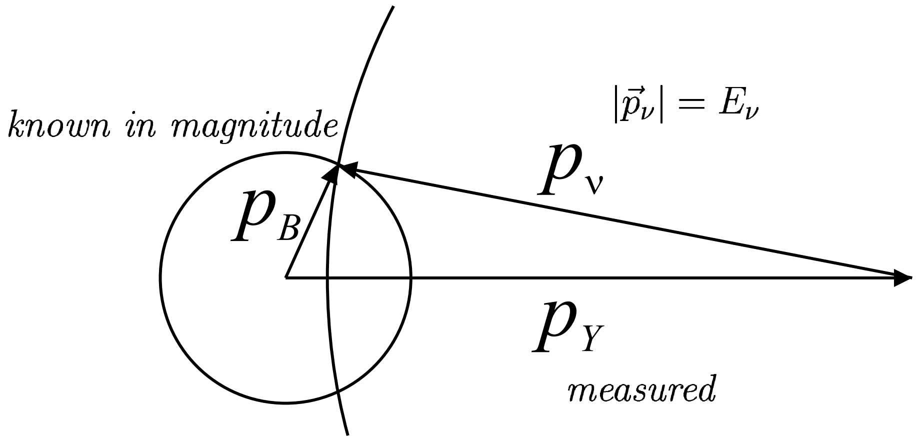
Signals are defined in the mass-difference $\Delta m = m(D^{**}_{rec}) - m(D^{0}_{rec})$, this improves the resolution since systematics cancel out.

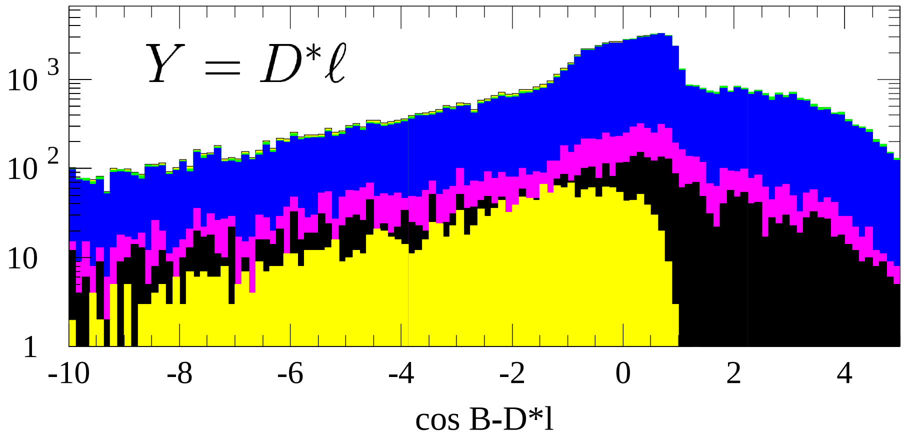
Separation of $B \to D^{**}\ell\nu$ and $B \to D^{*}\ell\nu$

$|\cos B, D^{**}\ell| < 1$



$$\cos(B,Y) = -\frac{m_B^2 + m_Y^2 - 2E_B E_Y}{2|\vec{p}_B||\vec{p}_Y|}$$

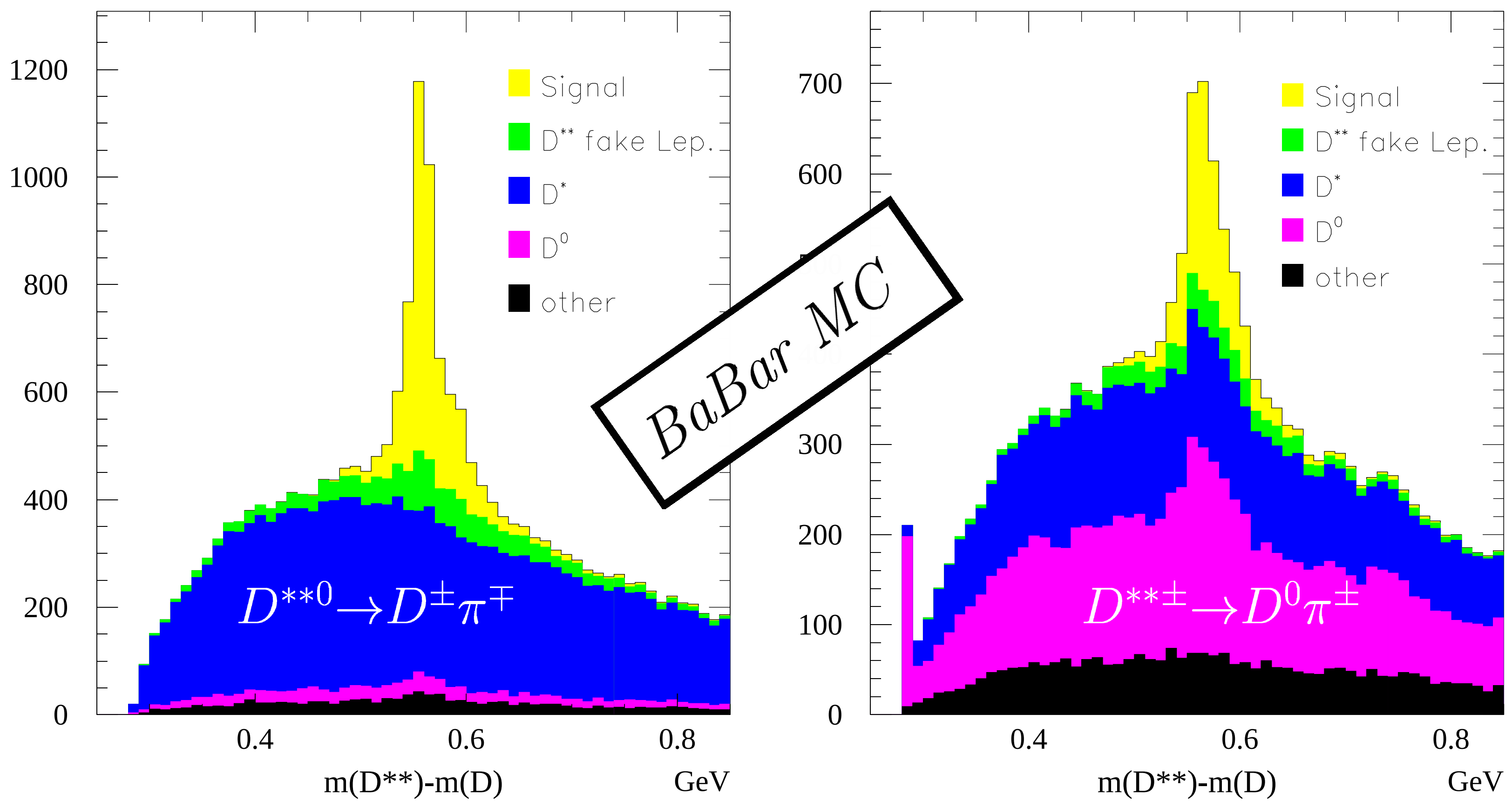




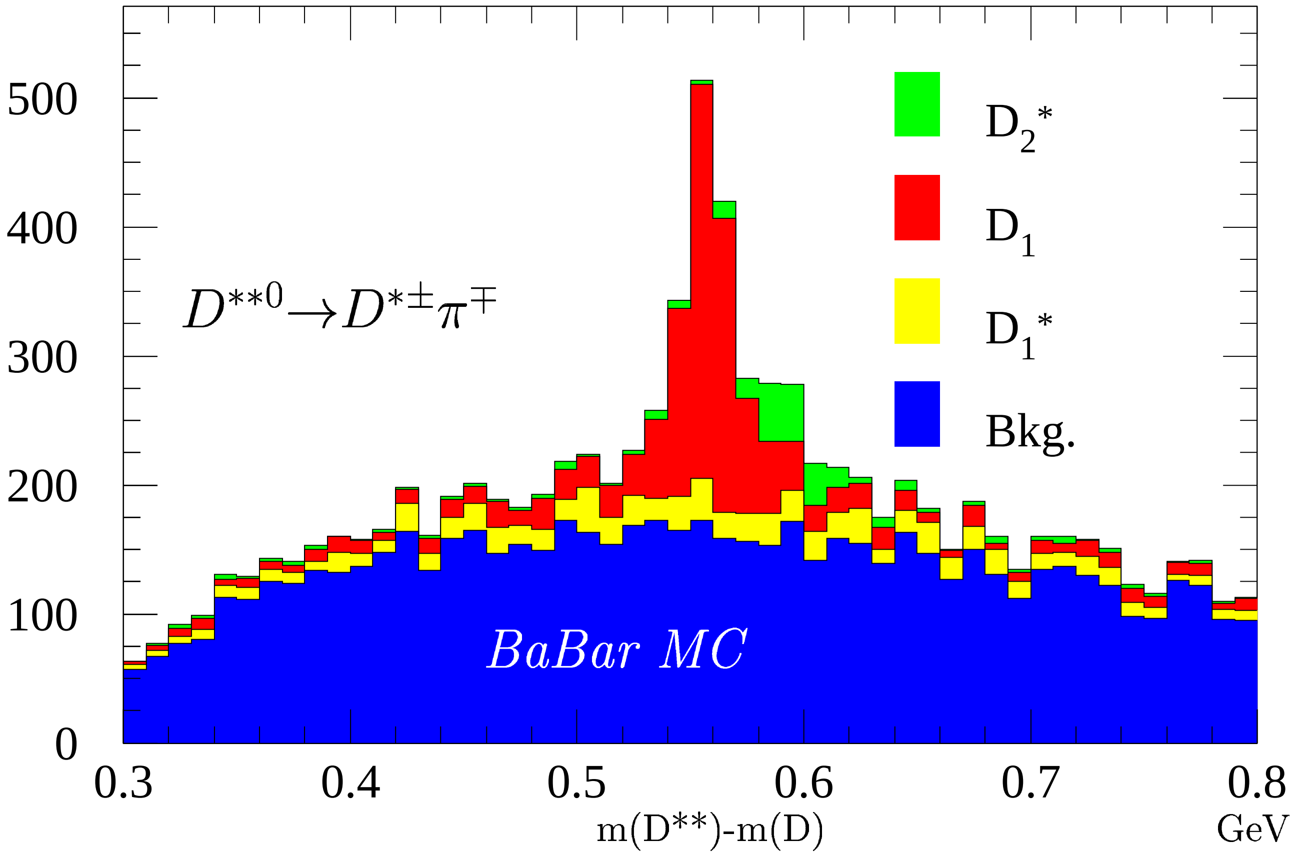
$\cos B, D^{*}\ell < -1$

Events should fullfill D^{**}-hypotheses but contradict the D^{*}-hypotheses

Signal Spectra $D^{**}\to D^{*}\pi$



Contributions to the D^{**} Signal



- Separation of D_1 and D_2^* is hardly possible from mass information alone
- Broad states and background do look alike – *those need a different approach*

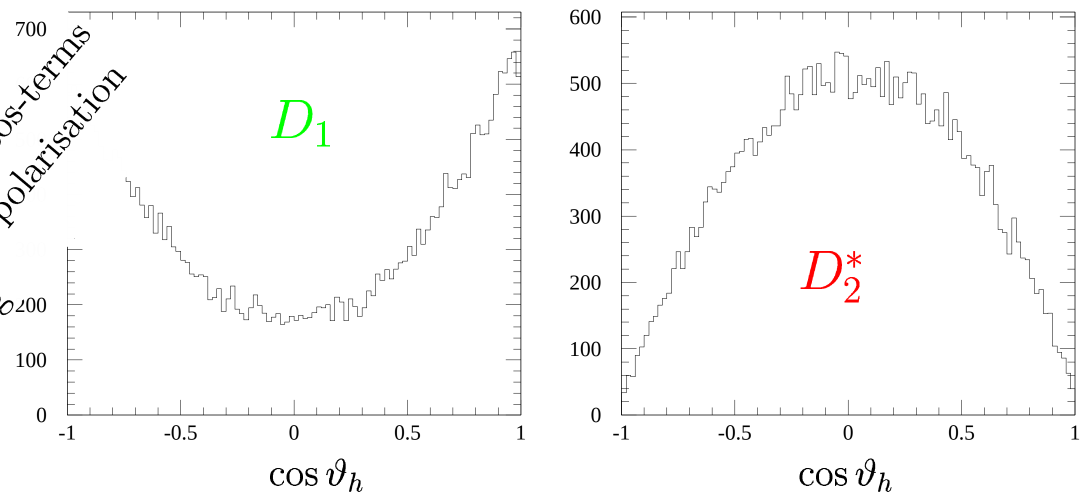
Helicity in $D^{**}\!\to\! D^*\pi$

The D-wave-decay of the D^{**} leaves the D^* polarised, depending on the total angular momentum of the decaying D^{**}:

$$D_1: \quad |1, m_z> \to L = |2,0> + D^* = \begin{cases} |1,+1> & \sim \sin^2\vartheta_h \\ |1,0> & \sim \cos^2\vartheta_h \\ |1,-1> & \sim \sin^2\vartheta_h \end{cases}$$

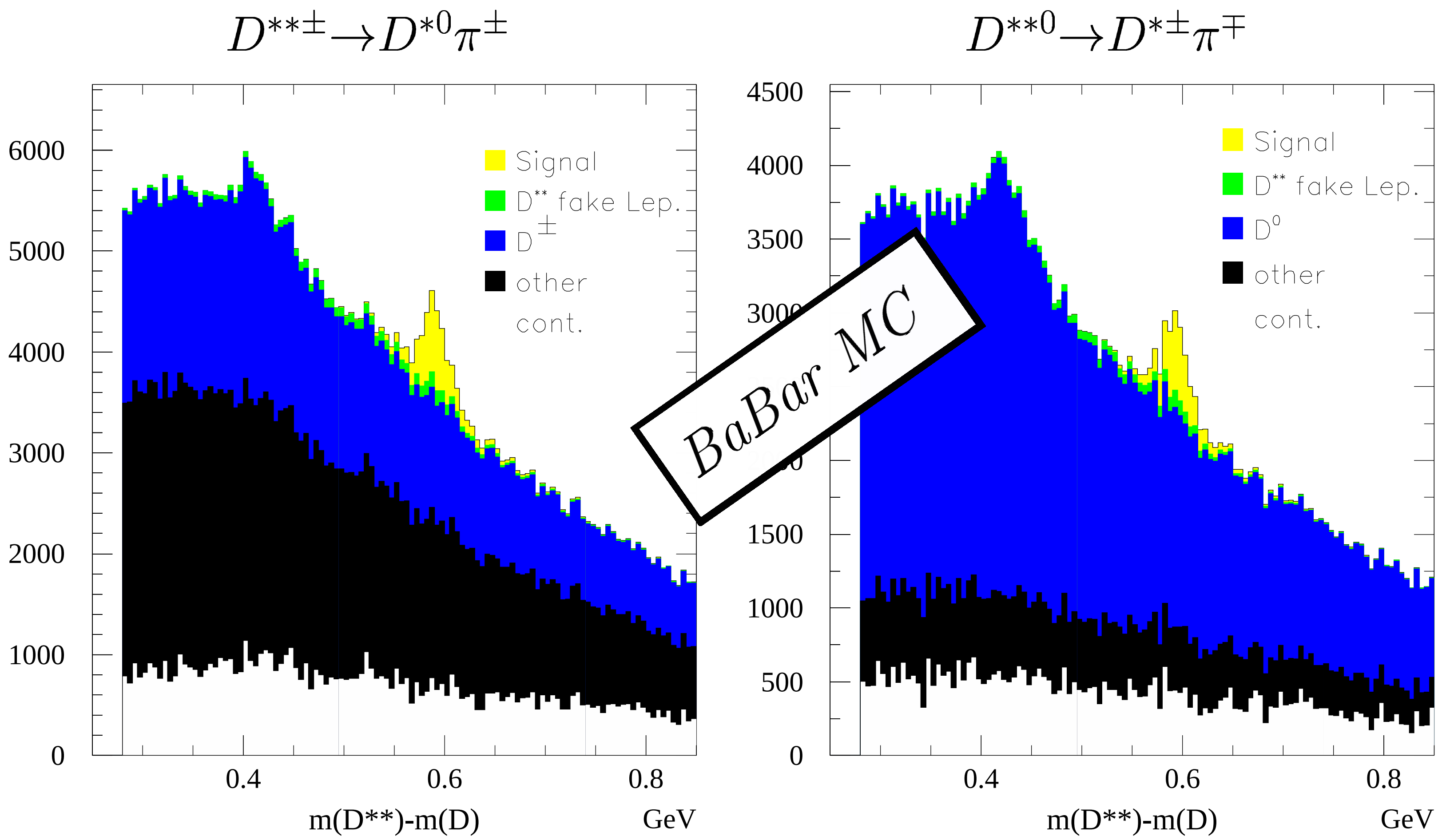
$$D_2^*: \quad |2, m_z> \to L = |2,0> + D^* = \begin{cases} |1,+1> & \sim \sin^2\vartheta_h \\ |1,-1> & \sim \sin^2\vartheta_h \end{cases}$$

ratio of sin- and cos-terms depending on polarisation and mixing



$\Rightarrow$ solution:
split the spectra into four bins of $|\cos\vartheta_h|$

Signal Spectra $D^{**}\to D\pi$



Combined Fit in All Channels

In total there are 10 spectra fitted in common:

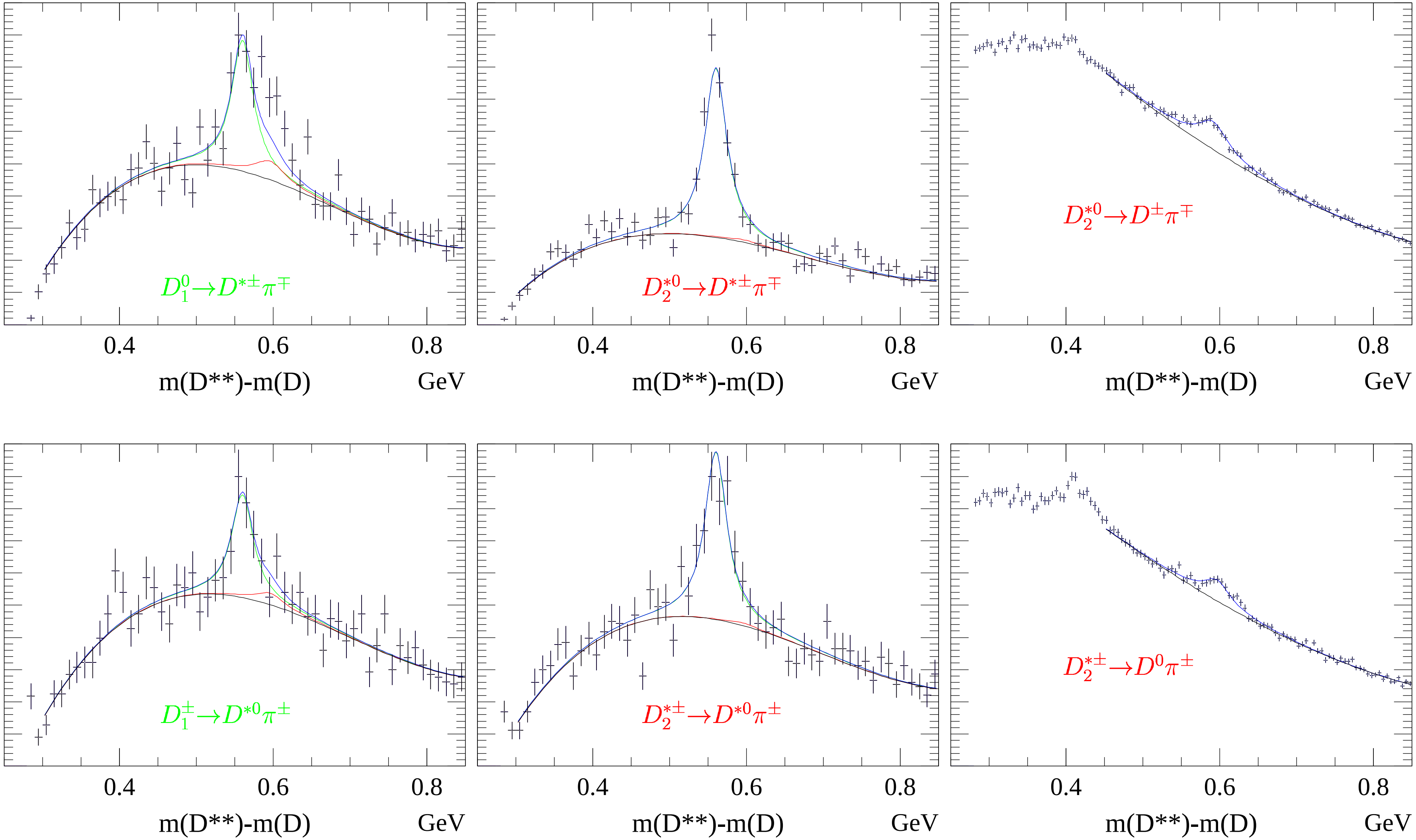
D^{**0}	$D^{\pm}\pi^{\mp}$	**(1)**	$D^{*\pm}\pi^{\mp}$with four bins in $\lvert\cos\vartheta_h\rvert$ containing D_2^{*0} and D_1^0 combined	**(4)**
$D^{**\pm}$	$D^0\pi^{\pm}$	**(1)**	$D^{*0}\pi^{\pm}$with four bins in $\lvert\cos\vartheta_h\rvert$ containing $D_2^{*\pm}$ and $D_1^{\pm}$ combined	**(4)**

All signals are described by 11 common parameters:

- branching ratios $\mathcal{B}(B \to D^{**}\ell\nu)$ **(4)**
- masses of D_1 and D_2^* – assumed to be charge independent **(2)**
- widths – assumed to be independent on D^* helicity **(4)**
- D_1-mixing – assumed to be the same for charged and neutral ones **(1)**

Signals are modelled by relativistic Breit-Wigner functions
Variation of the shapes due to different partial waves are neglected
Secondary branching fractions come from theoretical arguments

Fitted functions to $200 fb^{-1}$ BaBar-data



Preliminary Results with $200 fb^{-1}$ BaBar-Daten

	fit to data	fit to MC	MC input	
$\mathcal{BR}(B \to D_1^0 \ell\nu)$	5.35±0.28	5.92±0.25	5.6	$[10^{-3}]$
$\mathcal{BR}(B \to D_2^{*0} \ell\nu)$	3.35±0.32	3.59±0.20	3.7	$[10^{-3}]$
$\mathcal{BR}(B \to D_1^{\pm} \ell\nu)$	3.78±0.36	5.92±0.46	5.6	$[10^{-3}]$
$\mathcal{BR}(B \to D_2^{*\pm} \ell\nu)$	2.28±0.34	3.26±0.22	3.7	$[10^{-3}]$
mixing parameter	1.75±0.26	1.75±0.20	2.0	
χ^2/dof	999.3 / 571	220.9 / 571		

Systematic Uncertainties

Source	$\Delta\mathcal{BR}(B \to D^{**}\ell\nu)$ $[10^{-3}]$			
	D_1^0	D_2^{*0}	$D_1^\pm$	$D_2^{*\pm}$
statistic	0.28	0.32	0.36	0.34
efficiency, MC statistic	0.09	0.07	0.05	0.03
efficiency, detector effects	0.15	0.14	0.06	0.04
ongoing				
$\mathcal{BR}$ of secondary decays	0.10	0.12	0.06	0.05
dominated by D-decay				
$\mathcal{BR}$ of D^{**}-decays	where to get from ?			
fit-function	0.1	0.05	0.1	0.05
total	$0.28 \oplus 0.22$	$0.32 \oplus 0.20$	$0.36 \oplus 0.14$	$0.34 \oplus 0.08$
	0.36	0.38	0.39	0.35

Conclusion and Outlook

- Excitated D-mesons play an important role in the full understanding of B physics and contraints on HQET calculations
- Analysing the data taken at the BABAR B-factory all narrow resonances are accessible in different decay channels
- Contributions from different states can be disentangled using informations from mass and decay angels and also combining several decay modes
- Possible error sources like mixing of states or initial polarisation are determined from the data
- Systematic studies are under way
- Some more work is needed on consistency checks such as
  - combining charged and neutral states
  - seperate fitting of different decay modes
  - check for the prediction of $\mathcal{BR}(D_2^* \to D^*\pi)/\mathcal{BR}(D_2^* \to D\pi)$