2nd LHCb open semitauonic workshop

LAL, November 13-15 2017

Review on present experimental results on $B \to D^{(*,**)} \ell \nu$

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Outline

- $B \to D \ell \nu$
- $B \to D^* \ell \nu$
- $B \to D^{**} \ell \nu$
  - Resonances
  - Other states

BF measurements:
- Understanding of the SL compositions

Form factor shapes:
- Model for backgrounds in $R(D^{(*,**)})$ with muonic tau decays
- Allows to make reliable SM predictions of the corresponding R

- Summary of open issues and prospects

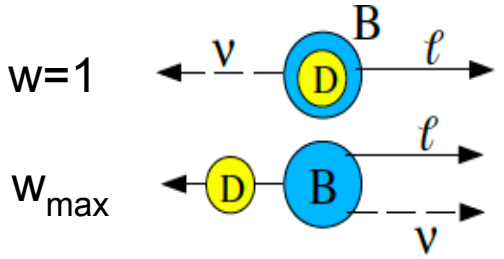
Exclusive $|V_{cb}|$ and Form Factors

Assuming $m_\ell = 0$

$B \to D^* \ell \nu$ $$\frac{d\Gamma}{dw} = \frac{G_F^2 m_{D^*}^3}{48\pi^3}(m_B - m_{D^*})^2 \sqrt{w^2-1}\,\chi(w)\mathcal{F}^2(w)|V_{cb}|^2$$

$B \to D \ell \nu$ $$\frac{d\Gamma}{dw} = \frac{G_F^2 m_D^3}{48\pi^3}(m_B + m_D)^2 (w^2-1)^{3/2}\mathcal{G}^2(w)|V_{cb}|^2$$

$$w = \frac{m_B^2 + m_D^2 - q^2}{2 m_B m_D}$$



Form Factor Parameterizations

- BGL Boyd, Grinstein, Lebed Phys.Rev.Lett 74, 4603 (1995)

$$f_i(z) = \frac{1}{P_i(z)\phi_i(z)} \sum_{n=0}^{N} a_{i,n} z^n, \qquad z(w) = \frac{\sqrt{w+1} - \sqrt{2}}{\sqrt{w+1} + \sqrt{2}}$$

Coefficient $a_{i,n}$ free parameters
Unitarity guarantees bounds on the sum of the $a_{i,n}^2$

- CLN Caprini, Lellouch, Neubert Nucl.Phys.B530, 153 (1998)

$B \to D \ell \nu$

$$\mathcal{G}(z) = \mathcal{G}(1)(1 - 8\rho^2 z + (51\rho^2 - 10)z^2 - (252\rho^2 - 84)z^3)$$

Higher order coefficient connected with the slope ρ^2

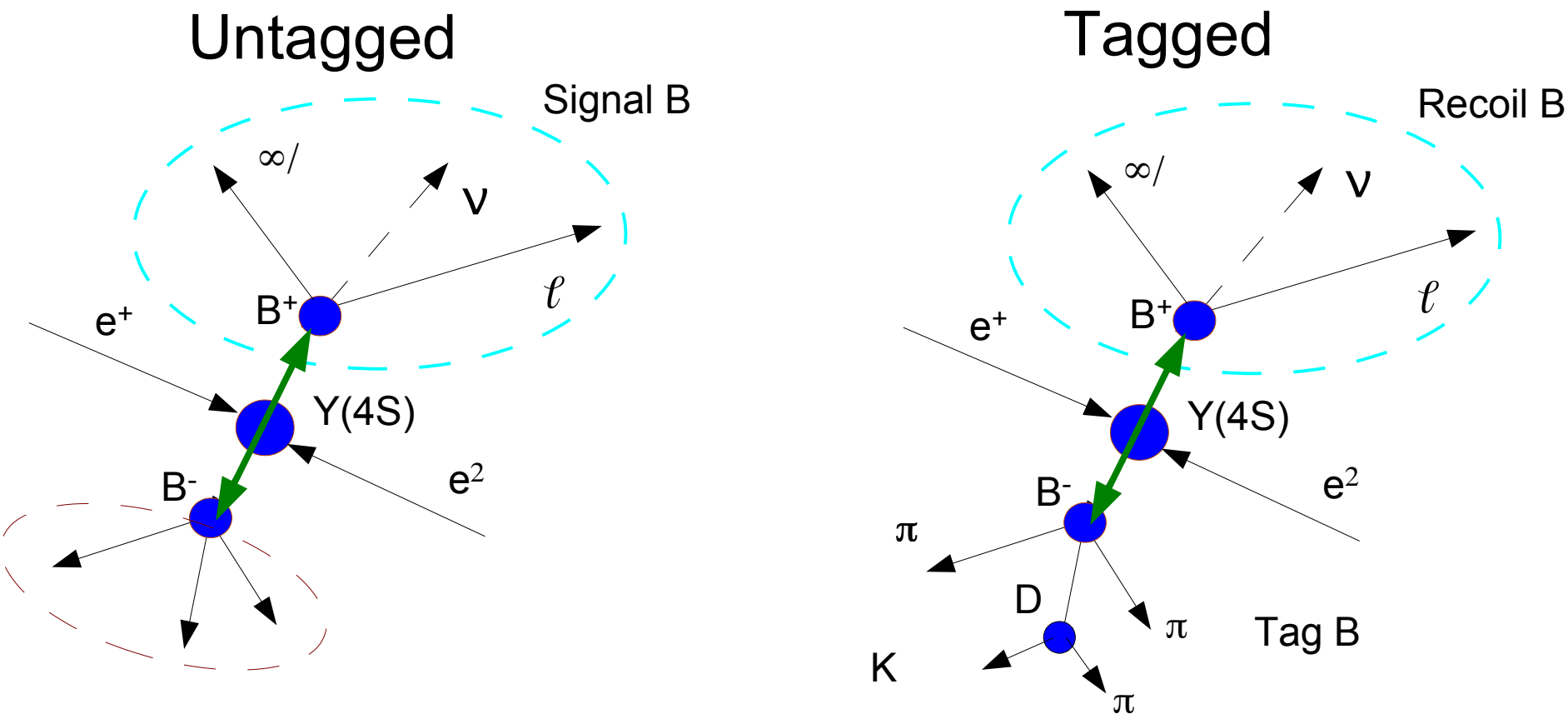
$B \to D^* \ell \nu$

$$\begin{aligned} h_{A_1}(w) &= h_{A_1}(1)\left[1 - 8\rho^2 z + (53\rho^2 - 15)z^2 \right. \\ &\quad \left. - (231\rho^2 - 91)z^3\right], \\ R_1(w) &= R_1(1) - 0.12(w-1) + 0.05(w-1)^2 \\ R_2(w) &= R_2(1) + 0.11(w-1) - 0.06(w-1)^2 \end{aligned}$$

Semileptonics at B-Factories

- Mostly studied at B-Factories BaBar, Belle, CLEO (some measurements performed at LEP experiments)

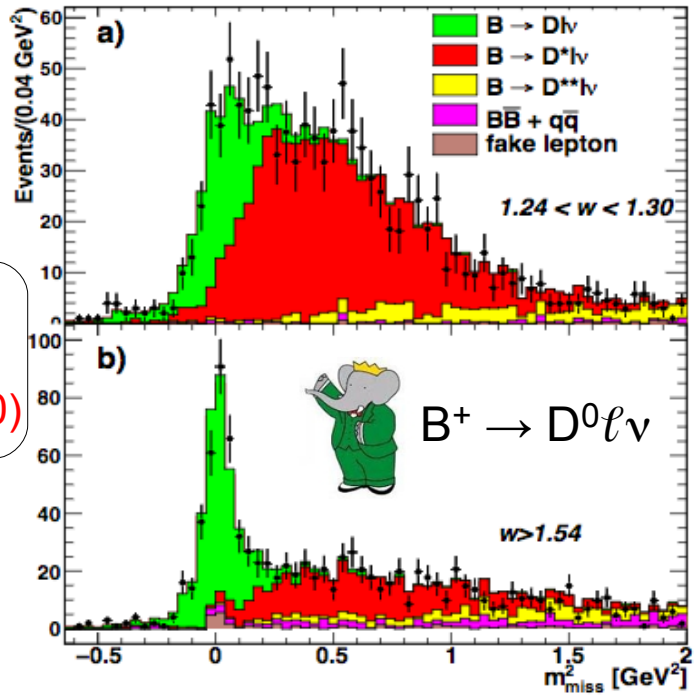
At B-Factories B produced from Y(4S) → BB decay, with a BF of ~100%.



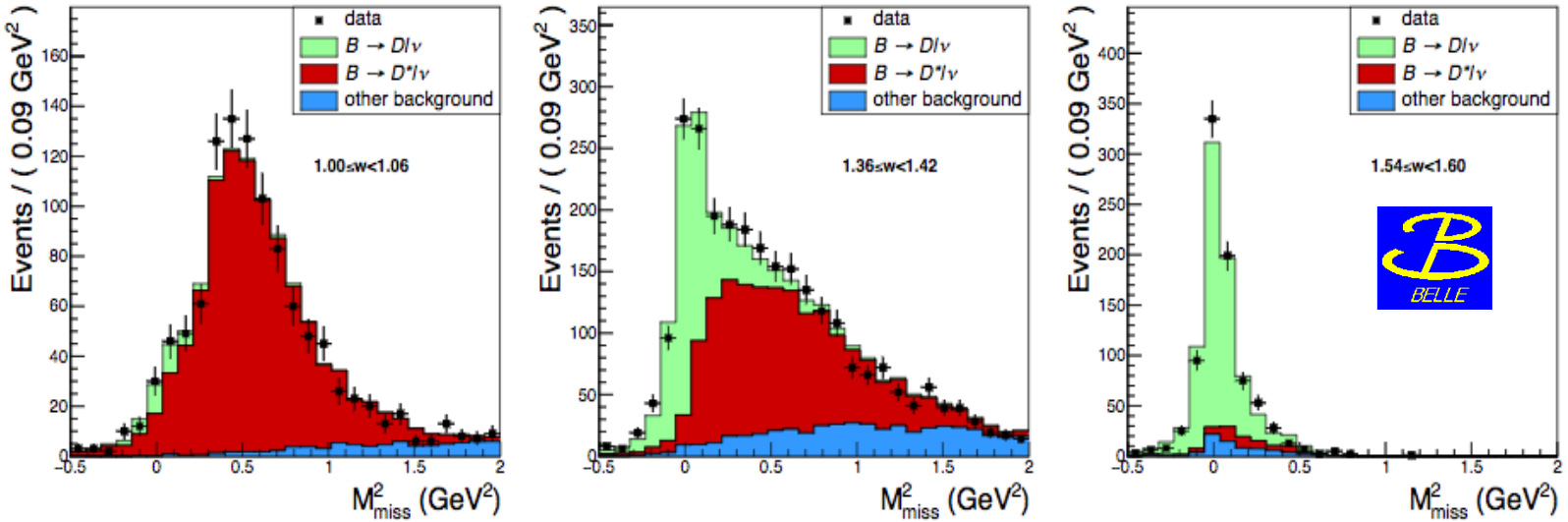
$B \to D \ell \nu$

- State of the art performed by BaBar and Belle with hadronic B tagging: reduces combinatorial backgrounds, cross-feeds and improves kinematic
  - $p(B_{sig}) = p_{e^+e^-} - p(B_{tag})$
- Use both $B \to D^0 \ell \nu$ and $B \to D^+ \ell \nu$
- Signal extract in 10 bins of w from M_{miss}^2
- Largest background
  - $B \to D^* \ell \nu$

BaBar used 460M $B\overline{B}$
Fit ~3200 signal events
Phys.Rev.Lett.104:011802(2010)

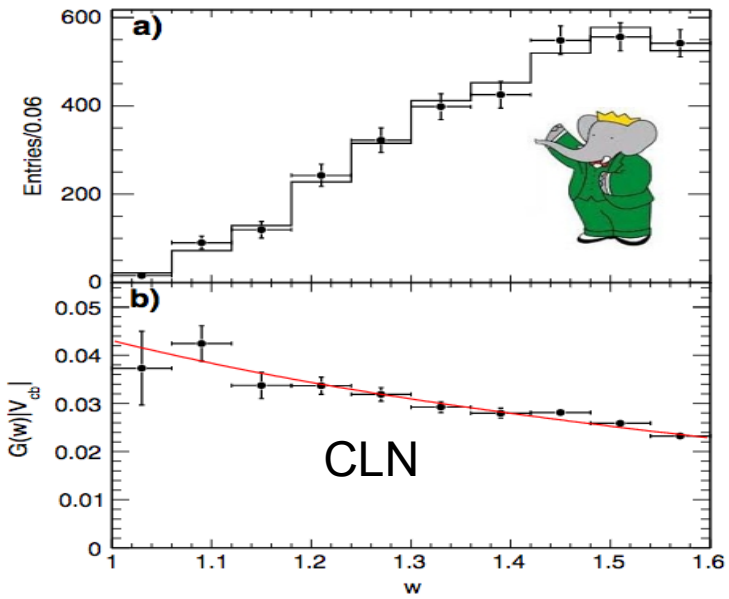


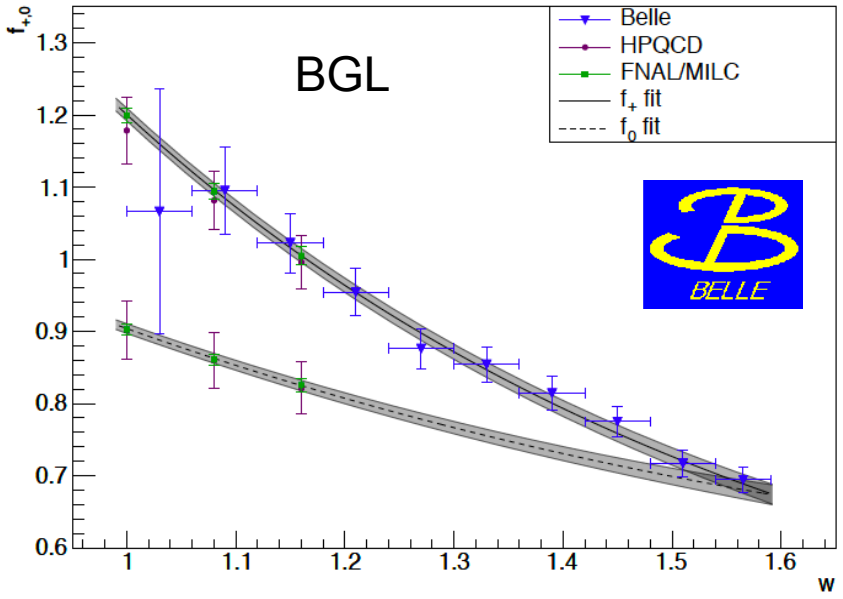
Belle used 771M $B\overline{B}$
Improved Hadronic B Tag based on NeuroBayes
Fit ~17000 signal events
Phys.Rev.D93:032006(2016)

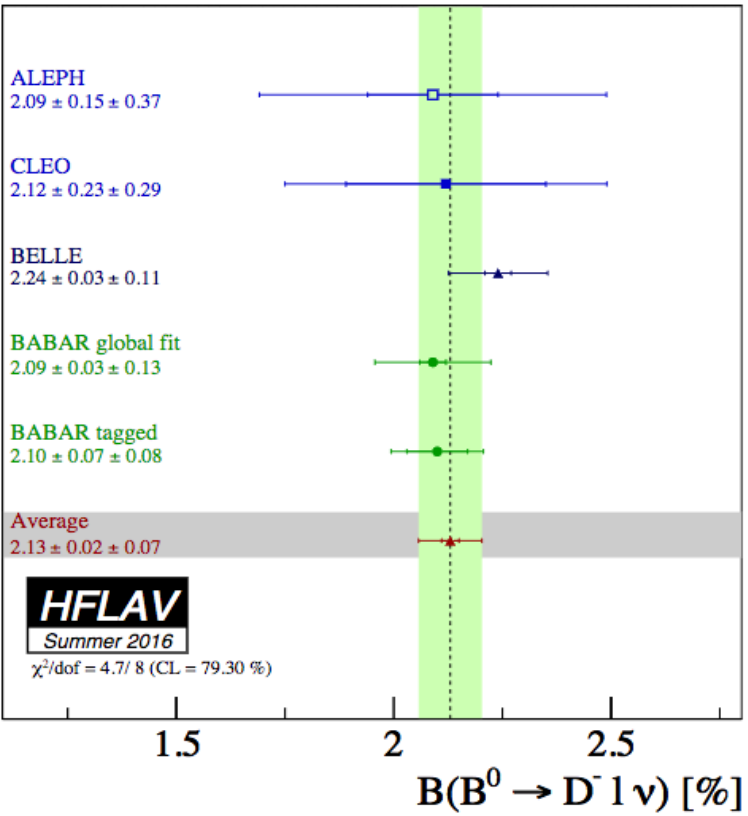


$B^+ \to D^0 \ell \nu$

$B \to D \ell \nu$







B^+

$B^0 + B^+$

$B^0 + B^+$

B^0 & B^+

$B^0 + B^+$

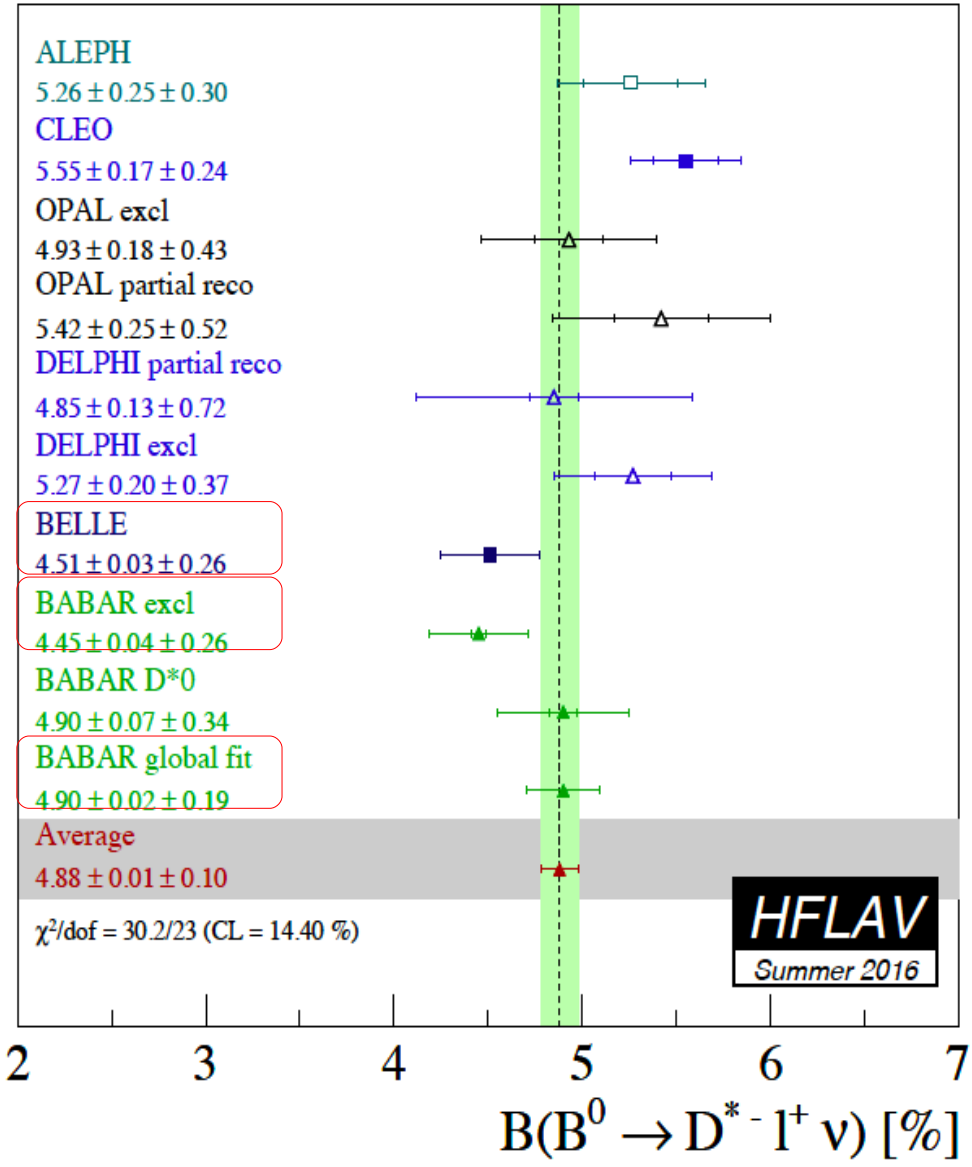
- Consistent results between the existing measurements
- Unfolded spectrum fitted with the Lattice from FNAL & HPQCD points to extract $|V_{cb}|$ and the form factor shapes
  - High precision R(D) results from FNAL & HPQCD with BaBar only data
  - Best prediction of R(D) using both Belle and BaBar data, R(D)=0.299(3)

Bigi, Gambino PRD 94, 094008 (2016)

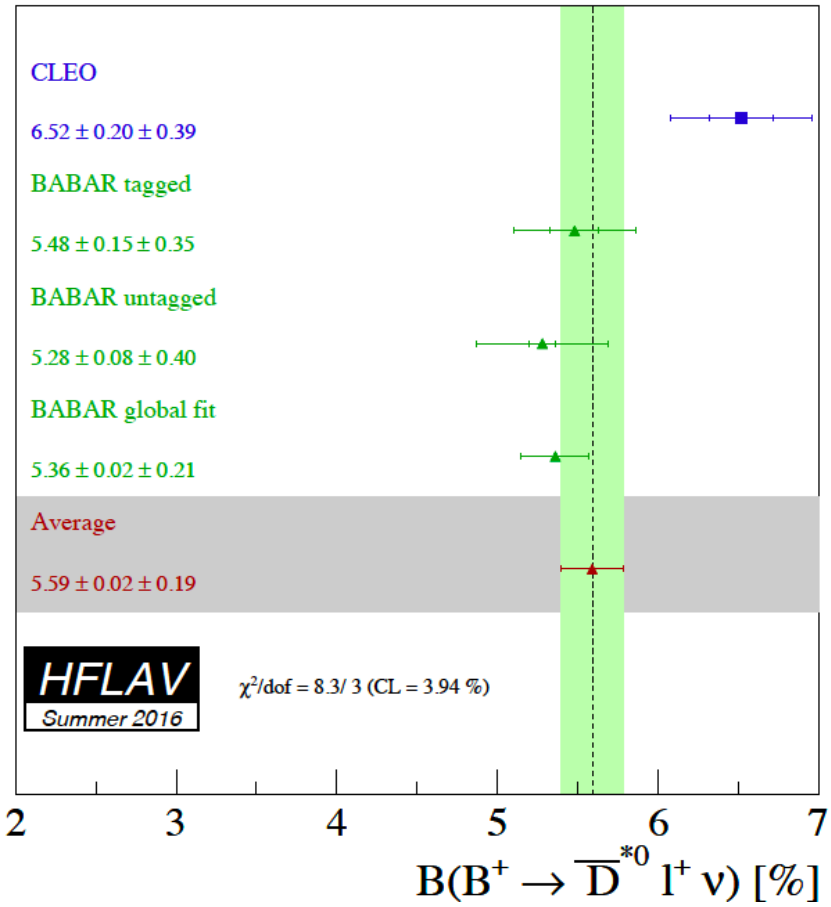
$B \to D^* \ell \nu$: status

- Most precise measurements are the Belle and BaBar measurements (untagged)

Both B^+ and B^0 (Isospin constraint)



Only B^+

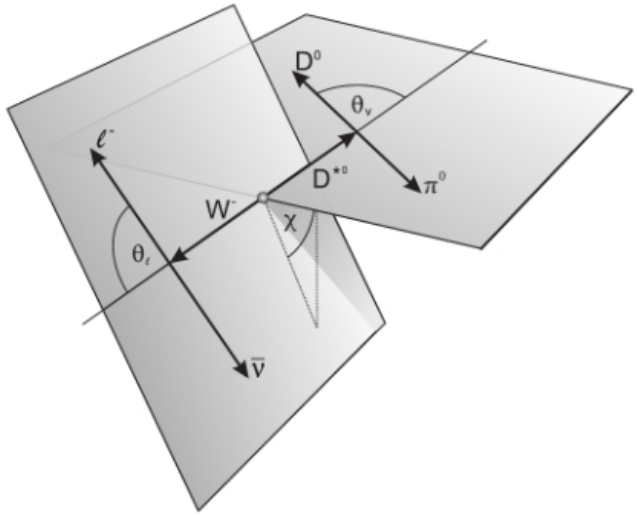


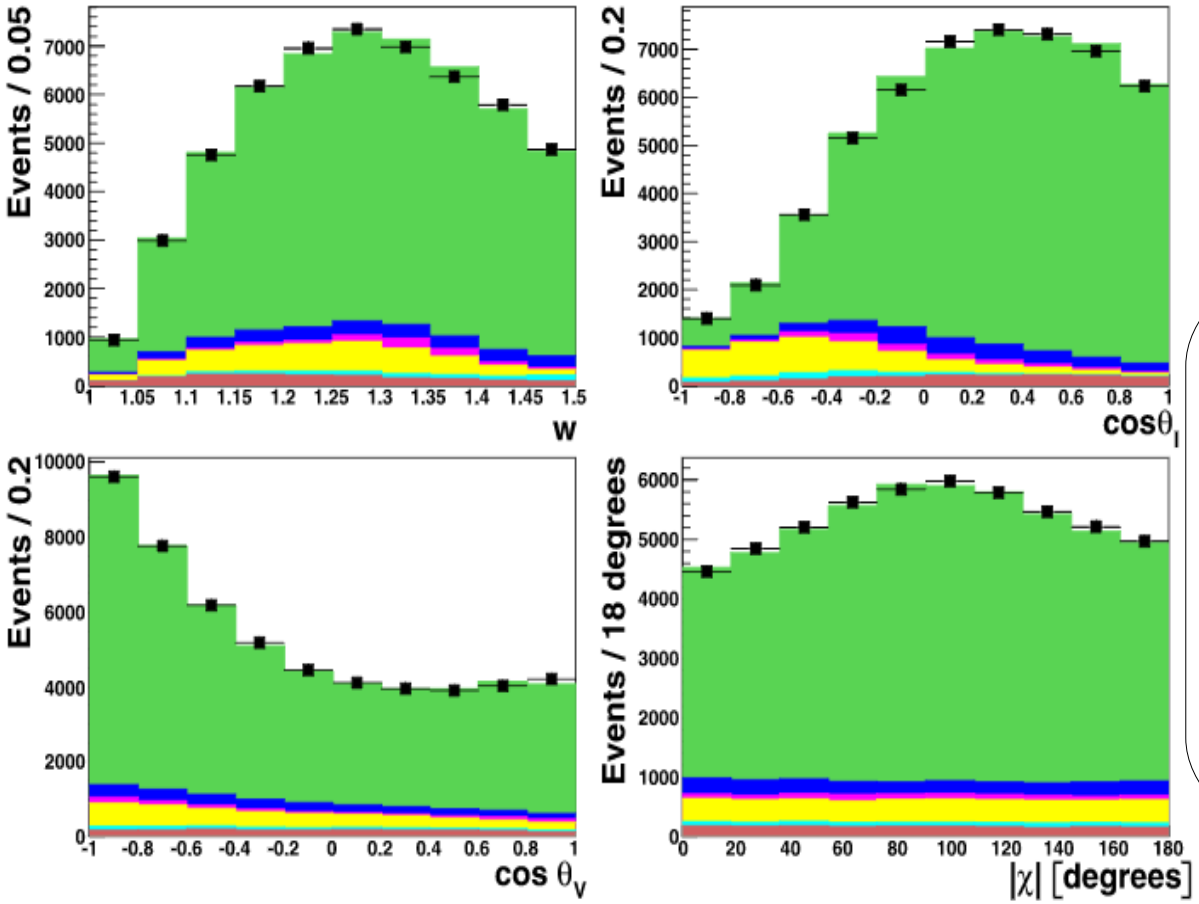
Good agreement between BaBar and Belle for the most precise measurements!
Few B^+ measurements available!

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

Phys.Rev.D82:112007,2010

- Considered neutral B decays, both el. and muons
  - $B^0 \to D^{*-} \ell \nu$ and $D^{*-} \to D^0 \pi^-$ only $D^0 \to K\pi$
- Signal extracted from cosBY and DeltaM
  - 120K events with 711 fb^{-1}
- Fit to projections in w, and decay angles





Fit is performed in various subsamples (run time, lepton energy range, ...) to control efficiencies and backgrounds and than the results averaged

Fit results with the CLN param.

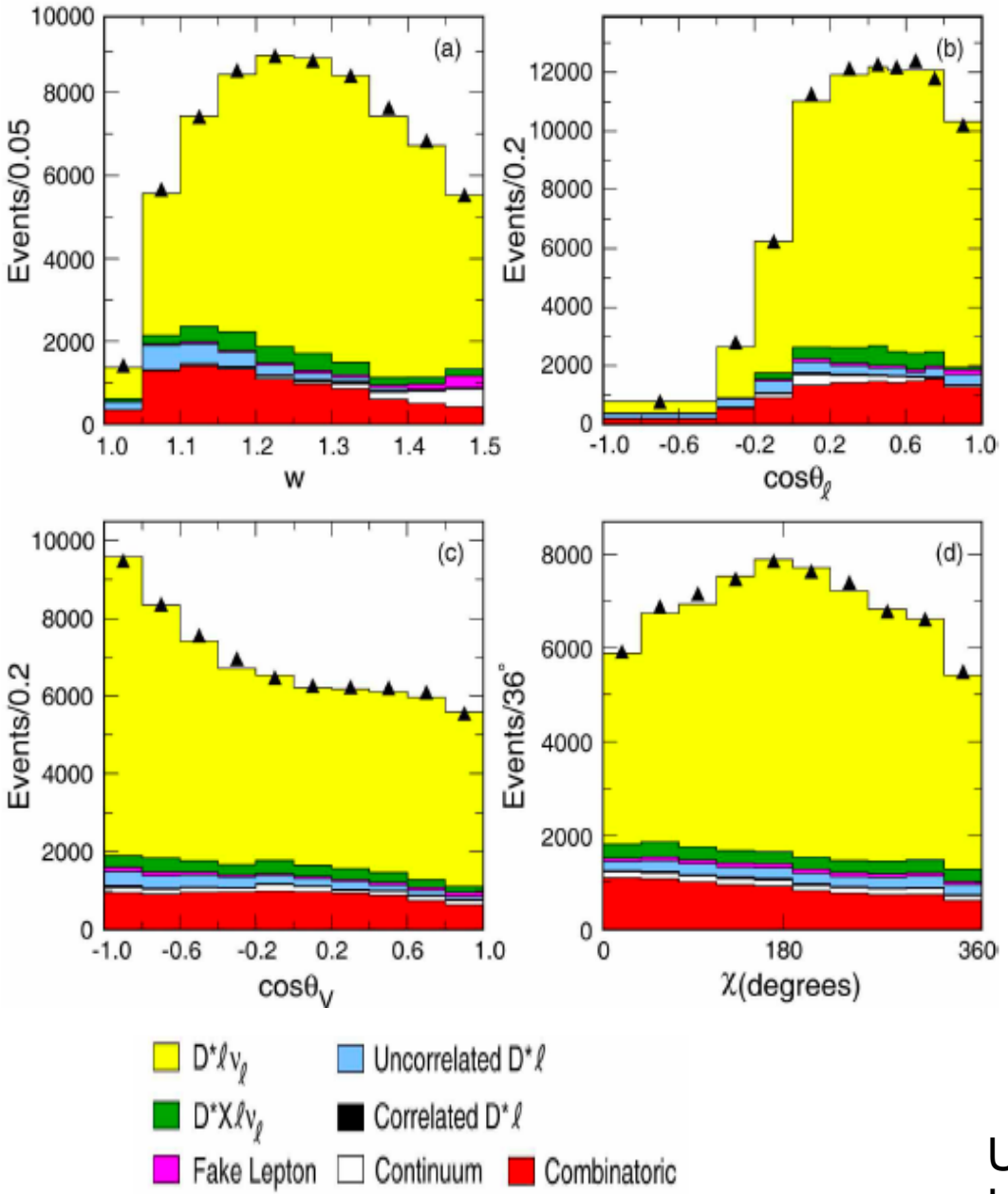
$$\begin{aligned}
\mathcal{F}(1)|V_{cb}| &= (34.6 \pm 0.2 \pm 1.0) \times 10^{-3} \\
\rho^2 &= 1.214 \pm 0.034 \pm 0.009, \\
R_1(1) &= 1.401 \pm 0.034 \pm 0.018, \\
R_2(1) &= 0.864 \pm 0.024 \pm 0.008, \\
\mathcal{B}(B^0 \to D^{*-} \ell^+ \nu_\ell) &= (4.58 \pm 0.03 \pm 0.26)\%.
\end{aligned}$$

$P(\chi^2)$=47%

Very good description of the data

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

Phys.Rev.D77:032002,2008



- Based on 79fb^{-1}
- Fitter 52.8 K signal events
  - $B^0 \to D^{*-} \ell \nu$ and $D^{*-} \to D^0 \pi^-$
  - 3 different D^0 decay modes
  - Fitted the projections, accounting for the proper bin-bin correlations directly from data

CLN parameterization

Subsample	ρ^2	$R_1(1)$	$R_2(1)$	$\mathcal{F}(1)\lvert V_{cb}\rvert \times 10^3$	χ^2/d.o.f.
$K\pi e$	0.971 ± 0.163	1.166 ± 0.182	0.977 ± 0.107	$34.76 \pm 0.61 \pm 0.61$	23.9/24
$K\pi\mu$	1.013 ± 0.175	1.193 ± 0.206	0.922 ± 0.123	$34.55 \pm 0.66 \pm 0.65$	37.9/24
$K\pi\pi\pi e$	1.581 ± 0.151	2.043 ± 0.384	0.405 ± 0.232	$33.30 \pm 1.27 \pm 0.96$	15.6/24
$K\pi\pi\pi\mu$	1.146 ± 0.258	1.156 ± 0.351	0.946 ± 0.197	$34.14 \pm 1.10 \pm 0.98$	28.0/24
$K\pi\pi^0 e$	1.042 ± 0.165	1.217 ± 0.206	0.926 ± 0.118	$34.86 \pm 0.64 \pm 1.46$	26.9/24
$K\pi\pi^0\mu$	1.170 ± 0.155	1.439 ± 0.228	0.838 ± 0.131	$34.38 \pm 0.74 \pm 1.46$	24.8/24

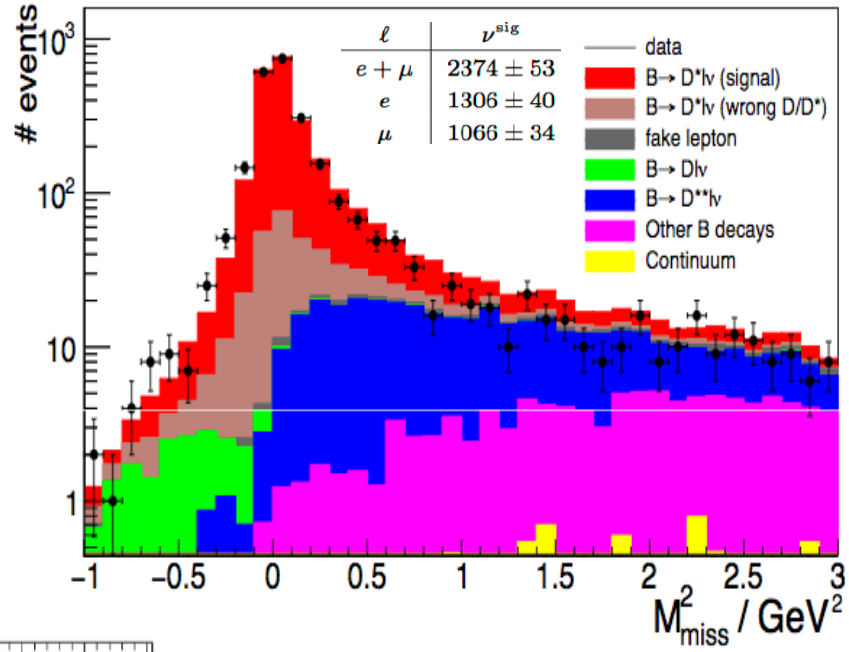
- Very good fit results: P(χ^2)=47%

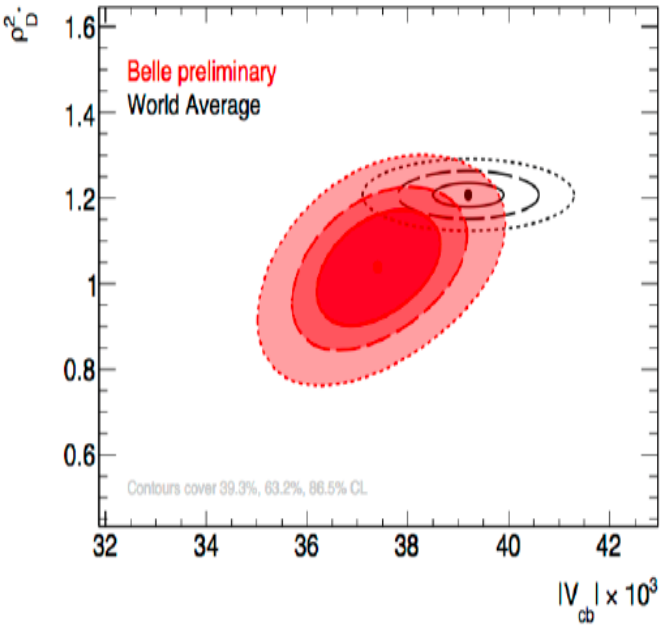
Unfortunately it is not easy to redo this analysis
Hopefully Belle will redo an untagged analysis with model-independent fits

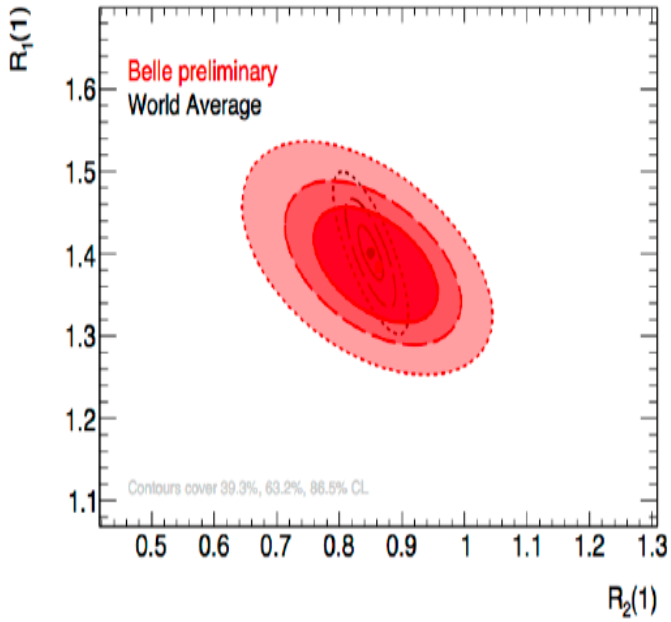
B → D*ℓν: news from Belle

ArXiv:1702.01521v2

- With the hadronic tag, similar to B → Dℓν
- Signal extracted from the missing mass distribution by an unbinned maximum likelihood fit
- Yields extracted in 4x10 bins of w and 3 angular variables: statistical correlations determined with bootstrapping technique







BF consistent with tWA

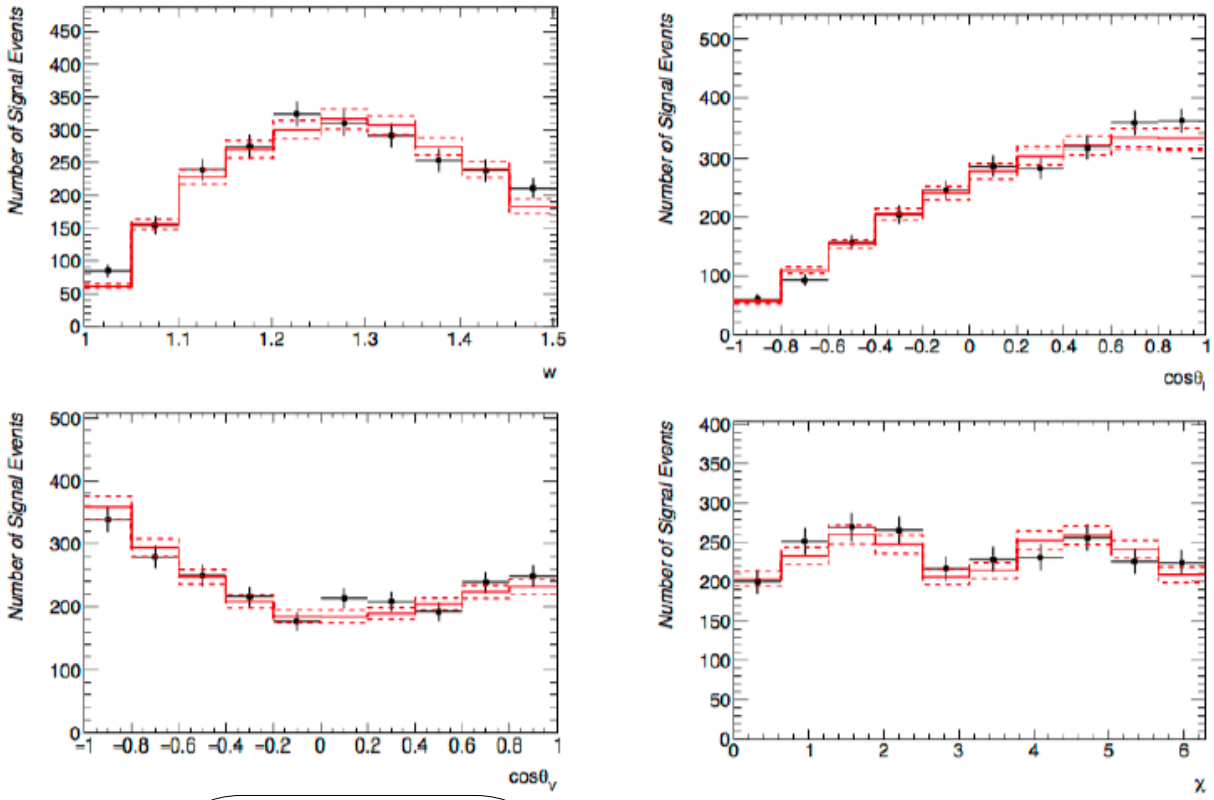
Belle fit with CLN parameterization consistent with world average

Parameter	This result	World Average
$\|V_{cb}\| \times 10^3$	37.4 ± 1.3	39.2 ± 0.7
$\rho^2_{D^*}$	1.03 ± 0.13	1.21 ± 0.03
$R_1(1)$	1.38 ± 0.07	1.40 ± 0.03
$R_2(1)$	0.87 ± 0.10	0.85 ± 0.02

$B \to D^* \ell \nu$: news from Belle

ArXiv:1702.01521v2

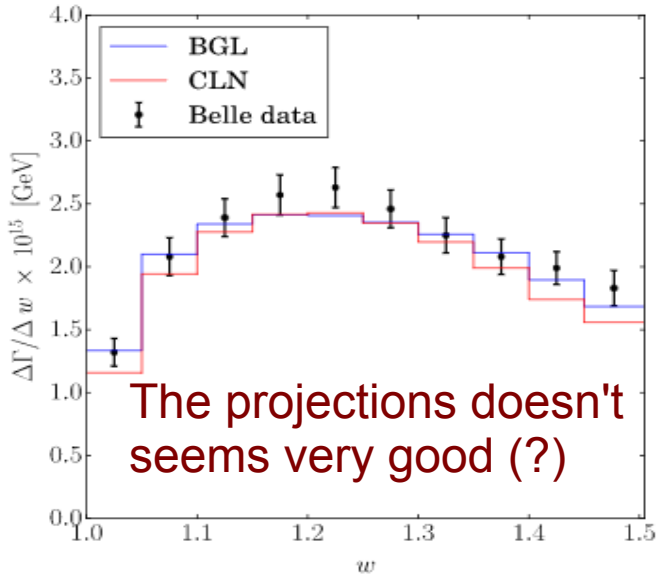
Belle Fit (CLN) on folded data



Parameter	folded result	unfolded result
$\|V_{cb}\| \times 10^3$	37.4 ± 1.3	38.2 ± 1.5
$\rho^2_{D^*}$	1.04 ± 0.13	1.17 ± 0.15
$R_1(1)$	1.38 ± 0.07	1.39 ± 0.09
$R_2(1)$	0.86 ± 0.10	0.91 ± 0.08

Published for the first time the unfolded 4-D angular distributions

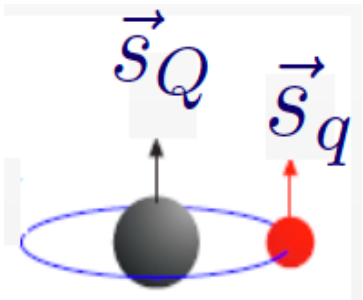
PLB 771 (2017)359-364



Problems in the unfolded data? Correlations?

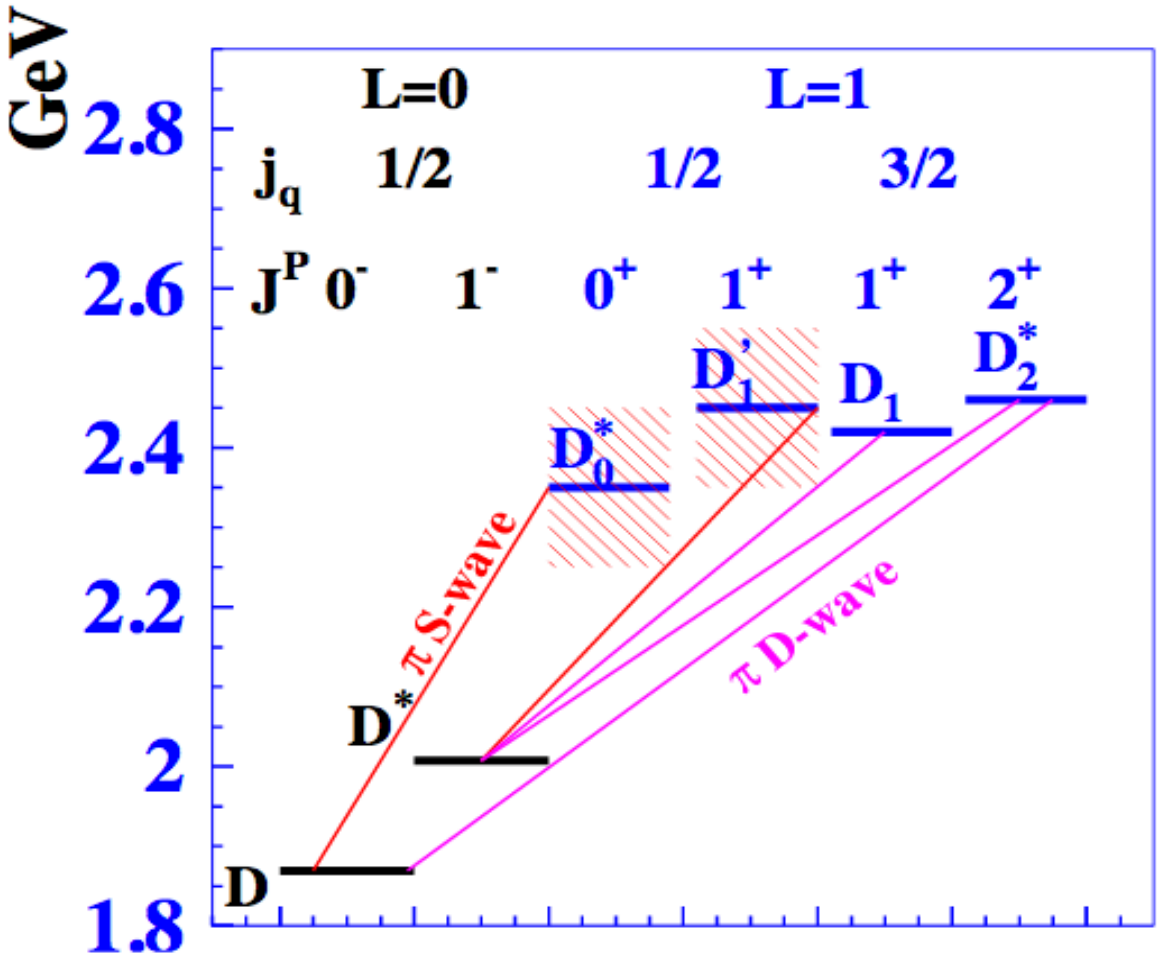
Hopefully Belle will soon provide an internal fit with BGL on this beautifully clean dataset!

D** states (L=1)



$$\vec{j}_q = \vec{L} + \vec{s}_{q=u,d,s}$$
$$\vec{J} = \vec{j}_q + \vec{s}_{Q=b,c}$$

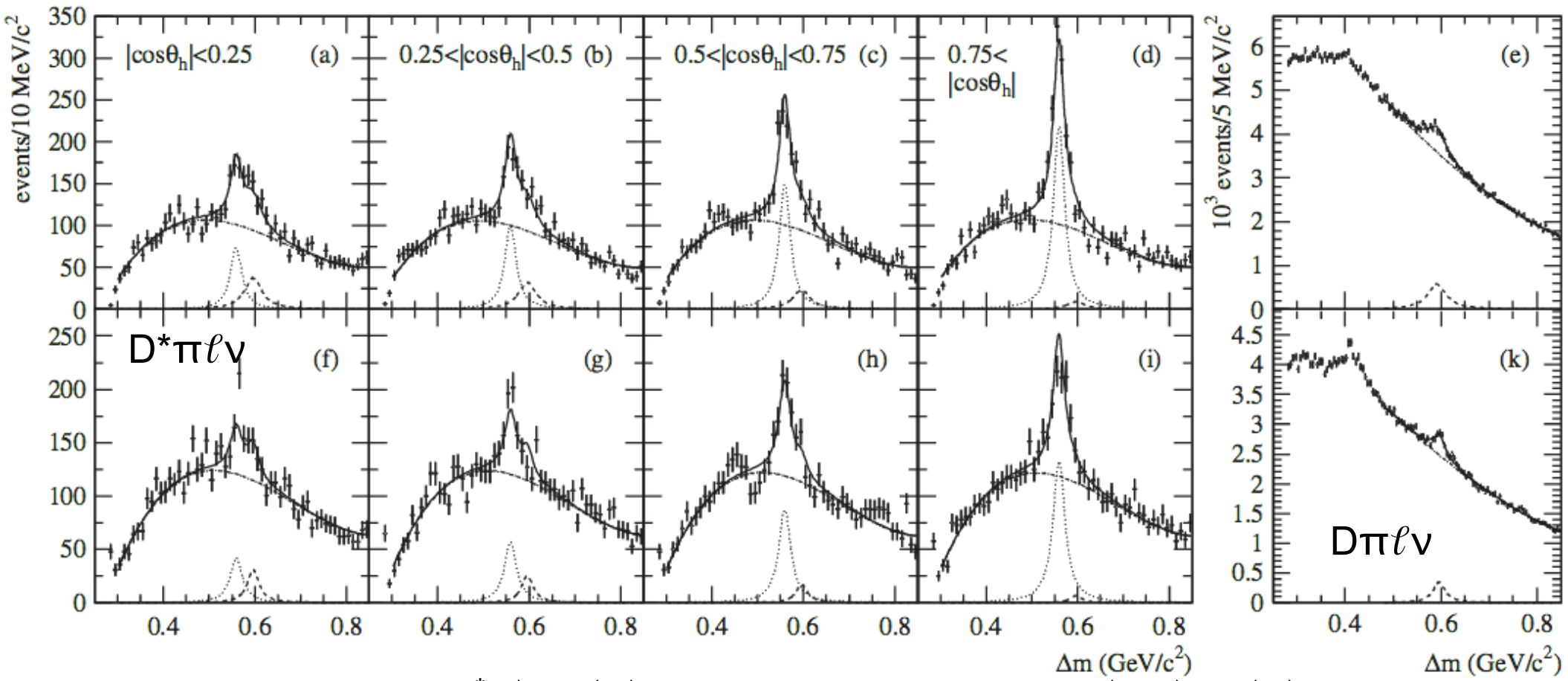
PDG
$D_1 \rightarrow D_1(2420)$
$D_1' \rightarrow D_1(2430)$



meson	L	j_l	J^P	mass $[GeV/c^2]$	width $[GeV/c^2]$	decay modes
D	0	1/2	0^-	1.867	-	various
D^*	0	1/2	1^-	2.009	-	$D\pi$, $D^0\gamma$
D_0^*	1	1/2	0^+	2.360	0.275	$D\pi^-$
D_1'	1	1/2	1^+	2.427	0.384	$D^*\pi^-$
D_1	1	3/2	1^+	2.422	0.026	$D^*\pi^-$, $D\pi^+\pi^-$
D_2^*	1	3/2	2^+	2.464	0.043	$D^*\pi^-$, $D\pi^-$

$B \to D_{1,2}^{3/2} \ell \nu$

PRL103,051803(2009)



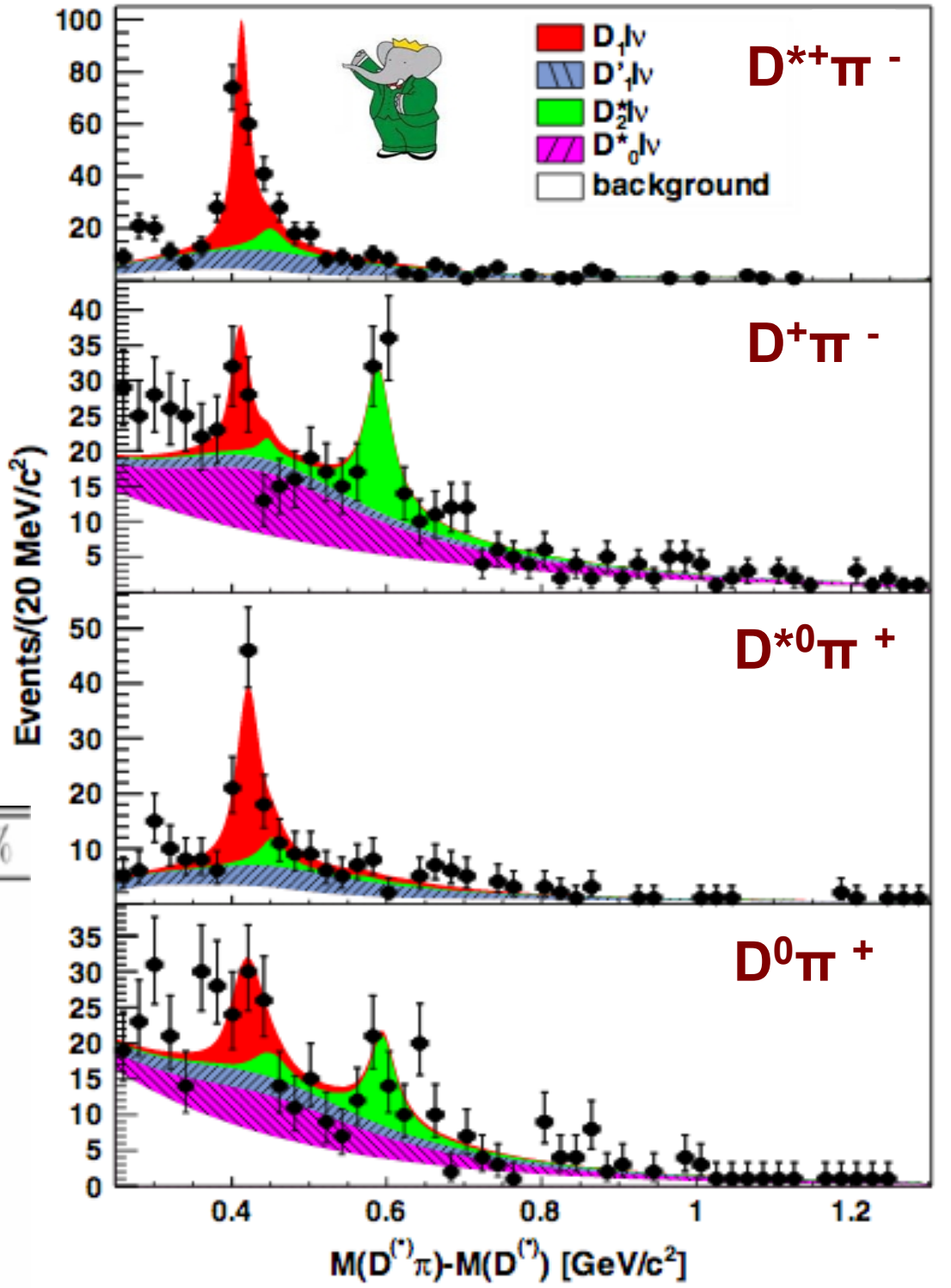
- Simultaneous fit to $M(D^*\pi)-M(D)$ in 4 bins of helicity and $M(D\pi)-M(D)$ to maximize the D_1, D_2^* separation
- Measure also
  - $(D_1 \to D\pi)/(D_1 \to D^*\pi)$
  - D_1 polarization

$$\mathcal{B}(B^+ \to D_1^0 \ell^+ \nu_\ell) \times \mathcal{B}(D_1^0 \to D^{*+}\pi^-) = (2.97 \pm 0.17_{\rm stat} \pm 0.17_{\rm syst}) \times 10^{-3}$$
$$\mathcal{B}(B^+ \to D_2^{*0} \ell^+ \nu_\ell) \times \mathcal{B}(D_2^{*0} \to D^{(*)+}\pi^-) = (2.29 \pm 0.23_{\rm stat} \pm 0.21_{\rm syst}) \times 10^{-3}$$
$$\mathcal{B}(B^0 \to D_1^- \ell^+ \nu_\ell) \times \mathcal{B}(D_1^- \to D^{*0}\pi^-) = (2.78 \pm 0.24_{\rm stat} \pm 0.25_{\rm syst}) \times 10^{-3}$$
$$\mathcal{B}(B^0 \to D_2^{*-} \ell^+ \nu_\ell) \times \mathcal{B}(D_2^{*-} \to D^{(*)0}\pi^-) = (1.77 \pm 0.26_{\rm stat} \pm 0.11_{\rm syst}) \times 10^{-3}$$

$B \to D^{**}\ell\nu$ PRL 101 261802

- Reconstruct $B \to D^{(*)}\pi^{\pm}\ell\nu$ in events tagged with hadronic B decays
- Simultaneous fit to $M(D^{(*)}\pi)$ or $M(D^{(*)}\pi)$ -$M(D^{(*)})$, including cross-feeds
- Background yield constrained from fit to B_{tag}mass. Shapes checked on wrong-sign data combinations
- Large rate for broad states!

Decay Mode	$\mathcal{B}(\bar{B} \to D^{**}\ell^-\bar{\nu}_\ell) \times \mathcal{B}(D^{**} \to D^{(*)}\pi)$ %
$B^- \to D_1^0\ell^-\bar{\nu}_\ell$	$0.29 \pm 0.03 \pm 0.03$
$B^- \to D_2^{*0}\ell^-\bar{\nu}_\ell$	$0.22 \pm 0.03 \pm 0.04$
$B^- \to D_1'^0\ell^-\bar{\nu}_\ell$	$0.27 \pm 0.04 \pm 0.05$
$B^- \to D_0^{*0}\ell^-\bar{\nu}_\ell$	$0.26 \pm 0.05 \pm 0.04$
$\bar{B}^0 \to D_1^+\ell^-\bar{\nu}_\ell$	$0.27 \pm 0.04 \pm 0.03$
$\bar{B}^0 \to D_2^{*+}\ell^-\bar{\nu}_\ell$	$0.10 \pm 0.04 \pm 0.03$
$\bar{B}^0 \to D_1'^+\ell^-\bar{\nu}_\ell$	$0.31 \pm 0.07 \pm 0.05$
$\bar{B}^0 \to D_0^{*+}\ell^-\bar{\nu}_\ell$	$0.44 \pm 0.08 \pm 0.06$

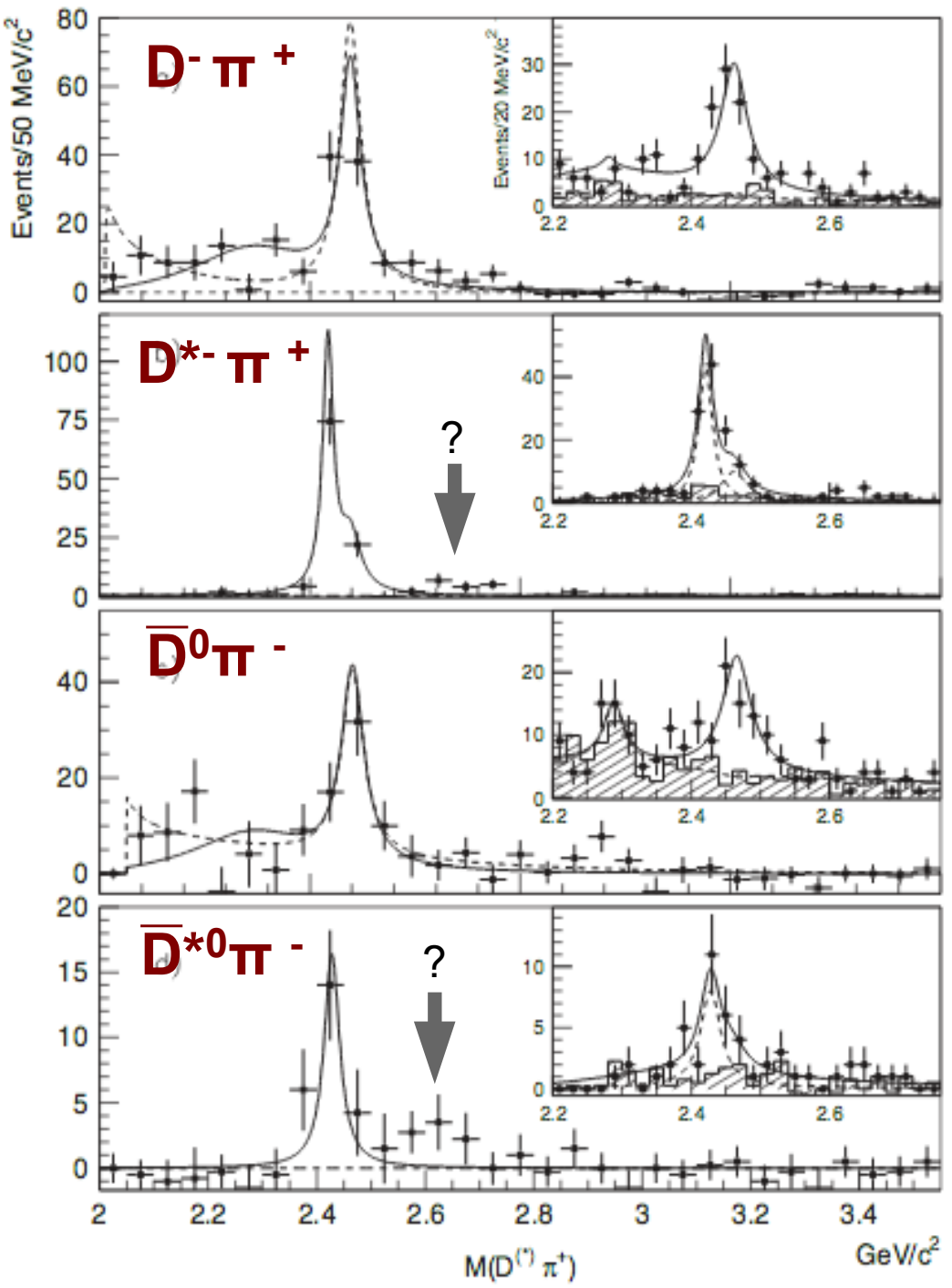


$B \to D^{**}\ell\nu$

PRD77,091503(2008)

- Similar technique
- Confirm D_1 and D_2^*
- Sees broad D_0^* but not D_1' !

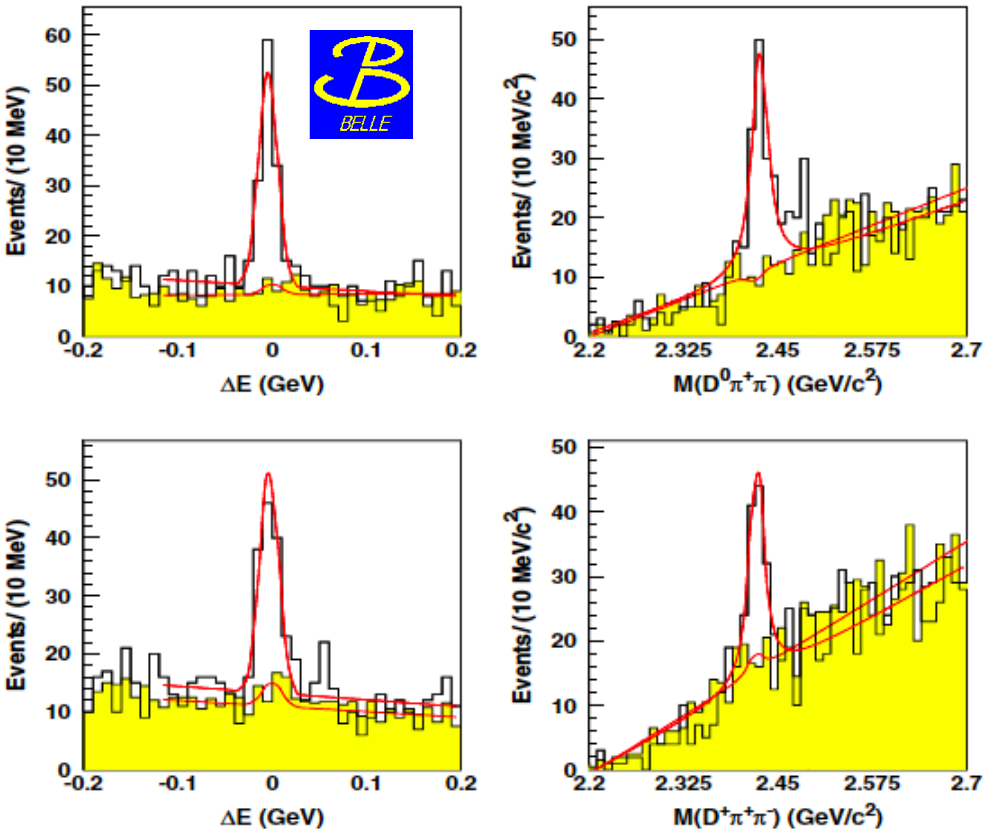
Mode	Yield	$\mathcal{B}$ (mode),%	Signif
$B^+ \to \bar{D}_0^{*0}\ell^+\nu$	102 ± 19	$0.24 \pm 0.04 \pm 0.06$	5.4
$B^+ \to \bar{D}_2^{*0}\ell^+\nu$	94 ± 13	$0.22 \pm 0.03 \pm 0.04$	8.0
$B^0 \to D_0^{*-}\ell^+\nu$	61 ± 22	$0.20 \pm 0.07 \pm 0.05$	2.6
		<0.4 @ 90% C.L.	
$B^0 \to D_2^{*-}\ell^+\nu$	68 ± 13	$0.22 \pm 0.04 \pm 0.04$	5.5
$B^+ \to \bar{D}_1^{\prime 0}\ell^+\nu$	-5 ± 11	<0.07 @ 90% C.L.	
$B^+ \to \bar{D}_1^{0}\ell^+\nu$	81 ± 13	$0.42 \pm 0.07 \pm 0.07$	6.7
$B^+ \to \bar{D}_2^{*0}\ell^+\nu$	35 ± 11	$0.18 \pm 0.06 \pm 0.03$	3.2
$B^0 \to D_1^{\prime -}\ell^+\nu$	4 ± 8	<0.5 @ 90% C.L.	
$B^0 \to D_1^{-}\ell^+\nu$	20 ± 7	$0.54 \pm 0.19 \pm 0.09$	2.9
		<0.9 @ 90% C.L.	
$B^0 \to D_2^{*-}\ell^+\nu$	1 ± 6	<0.3 @ 90% C.L.	



D** decays beyond D*π and Dπ

- Belle first observation of $D_1 \to D\pi\pi$ ($D\pi$ non D*) in $B \to D^{**}\pi$ decays (no evidence of $D^*\pi\pi$)
- No evidence of $D_2^* \to D\pi\pi$
- What about the wide resonances?

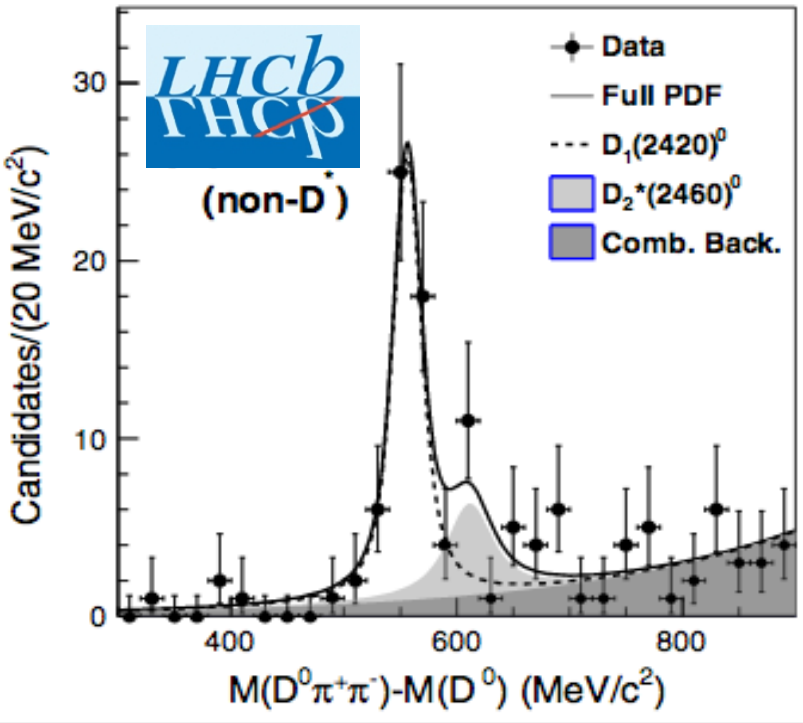
PRL94,221805(2015)



- LHCb confirmed in hadronic 4 body decays $B \to D\pi\pi\pi$

$$\mathcal{B}(B^- \to D_1(2420)^0\pi^+,\ D_1(2420)^0 \to D^{*+}\pi^-) = (5.8 \pm 1.0 \pm 0.9) \times 10^{-4}$$

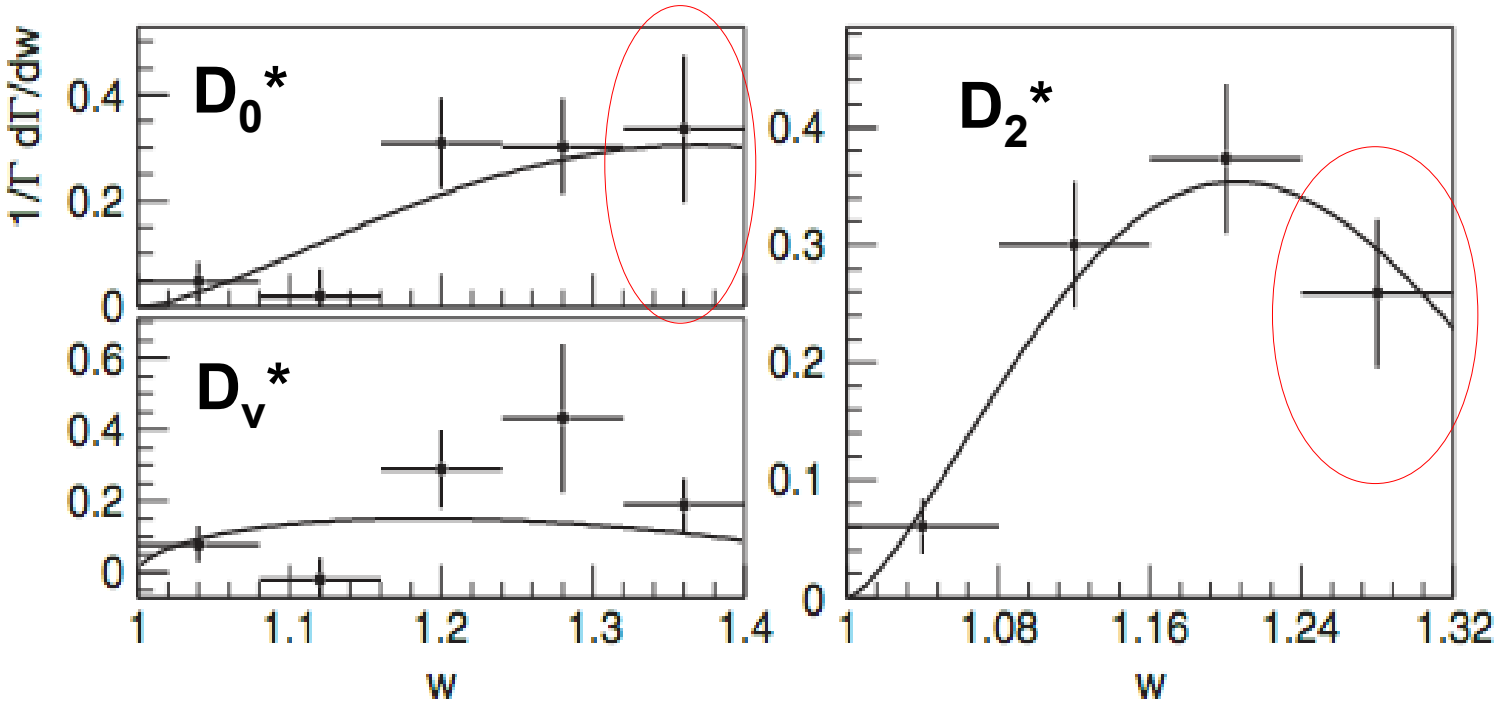
$$\mathcal{B}(B^- \to D_1(2420)^0\pi^+,\ D_1(2420)^0 \to D^0\pi^+\pi^-)_{\text{non-}D^*} = (2.5 \pm 0.4 \pm 0.4) \times 10^{-4}$$



B → D** form factors

PRD77,091503(2008)

- Study of the B → D** transition in bins of $w=v_B \cdot v_{D^{**}}$
- In HQET, at leading order, the B→D(*,**) are described by three universal IW function $\xi(w)$,$\tau_{1/2}(w)$ and $\tau_{3/2}(w)$
  - Fit with model described in Phys. Lett. B 520, 25 (2001)
    - $\tau(w)= \tau(1)[1+\tau' (w-1)]$ and $\tau'_{1/2}= \tau'_{3/2} + 0.5$



From a combined fit

- $\tau'_{3/2} = -1.8 \pm 0.3$
- $\tau_{3/2}(1) = 0.75$
- $\tau_{1/2}(1) = 1.28$

Due to the large D_0^* contribution, $\tau_{1/2}(1)$ is larger than expected

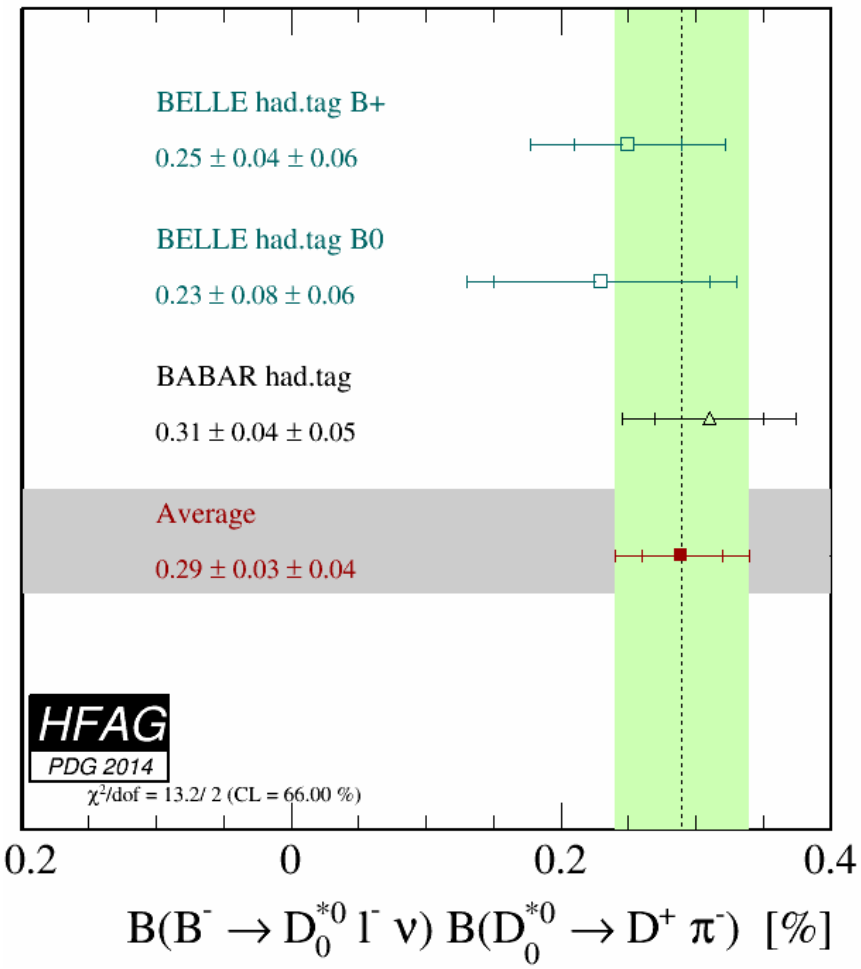
$$\tau_{1/2}(1) = 0.296(26)$$
$$\tau_{3/2}(1) = 0.526(23)$$

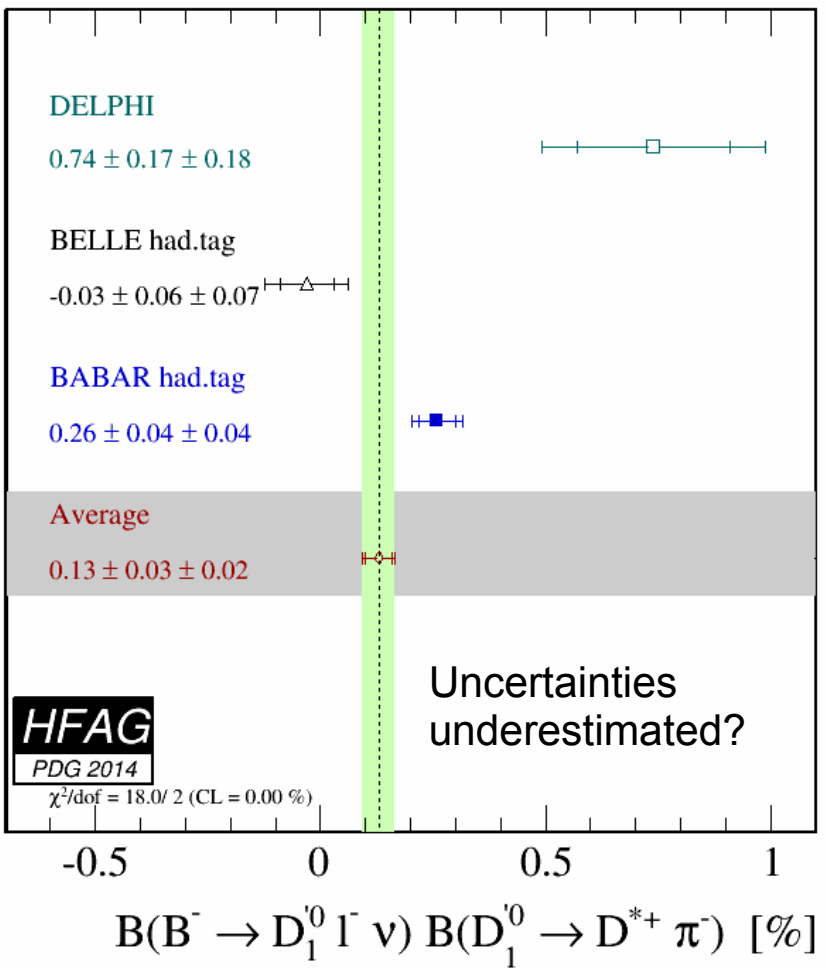
JHEP06(2009)022

- Helicity distribution confirms that the fitted broad component is consistent with the expected quantum numbers

Expect large B-->$D_0^*\pi$

$B \to D^{**} \ell \nu$ Wide resonances $D^{1/2}$





Consistent picture for D_0^* (more statistics ?)

$B^+ \to D_0^{*0} \ell\nu$ $D_0^{*0} \to D^+\pi^-$

HFAG 0.29 ± 0.03± 0.04

Dπ 0.43 ± 0.08

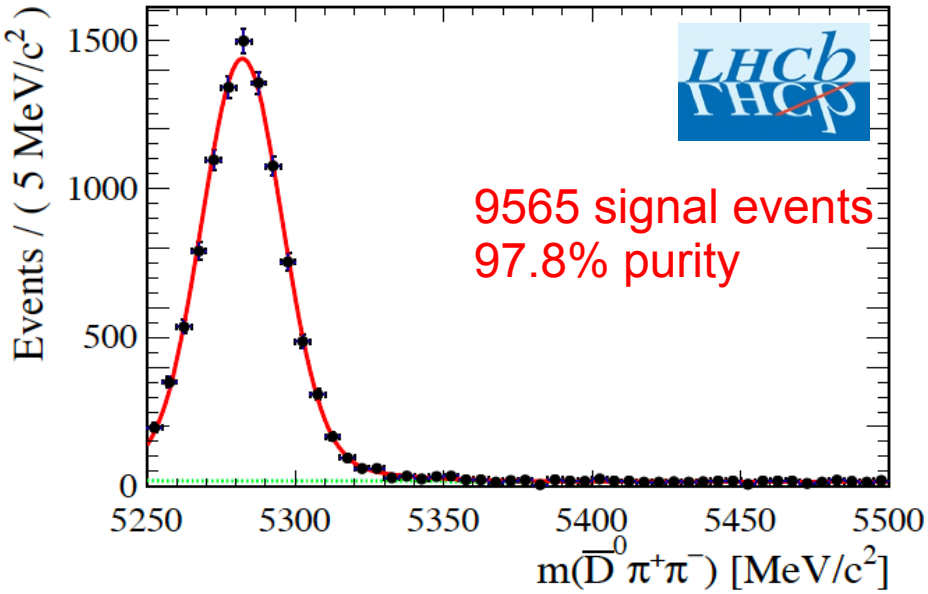
Not very consistent picture for D_1'

$B^+ \to D_1'^0 \ell\nu$ $D_1'^0 \to D^{*+}\pi^-$

HFAG 0.13 ± 0.03± 0.02

D*π 0.19 ± 0.05

Dalitz analysis of $B^0 \to \bar{D}^0 \pi^+ \pi^-$ PRD92,032002(2015)



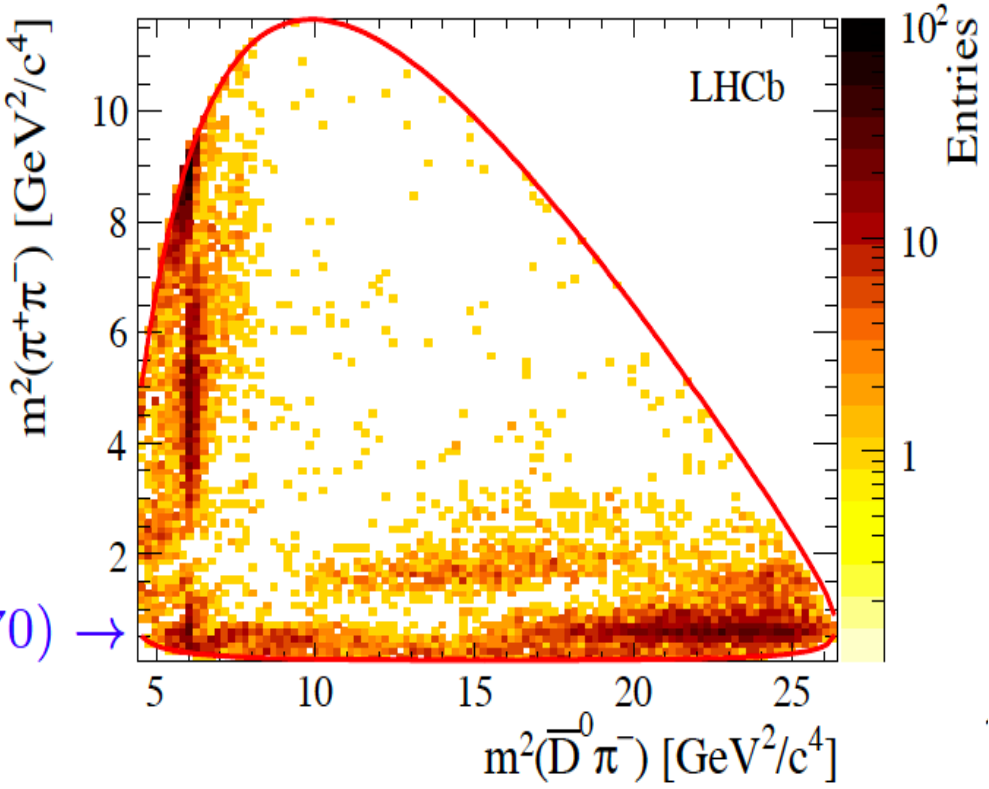
- Large yields to study D** structure and light resonances in $\pi^+\pi^-$
- Study Dπ natural parity states
  - JP = $0^+, 1^-, 2^+, 3^-$

Resonance	Isobar ($\mathcal{F}_i$ %)	K-matrix ($\mathcal{F}_i$ %)
$\bar{D}^0\pi^-$ P-wave	$9.21 \pm 0.56 \pm 0.24 \pm 1.73$	$9.22 \pm 0.58 \pm 0.67 \pm 0.75$
$D_0^*(2400)^-$	$9.00 \pm 0.60 \pm 0.20 \pm 0.35$	$9.27 \pm 0.60 \pm 0.86 \pm 0.52$
$D_2^*(2460)^-$	$28.83 \pm 0.69 \pm 0.74 \pm 0.50$	$28.13 \pm 0.72 \pm 1.06 \pm 0.54$
$D_3^*(2760)^-$	$1.22 \pm 0.19 \pm 0.07 \pm 0.09$	$1.58 \pm 0.22 \pm 0.18 \pm 0.07$

- D_0^*/D_2^* ratio not consistent with SL observations (?)
  - A reanalysis is needed!

$\downarrow D_2^*(2460)$

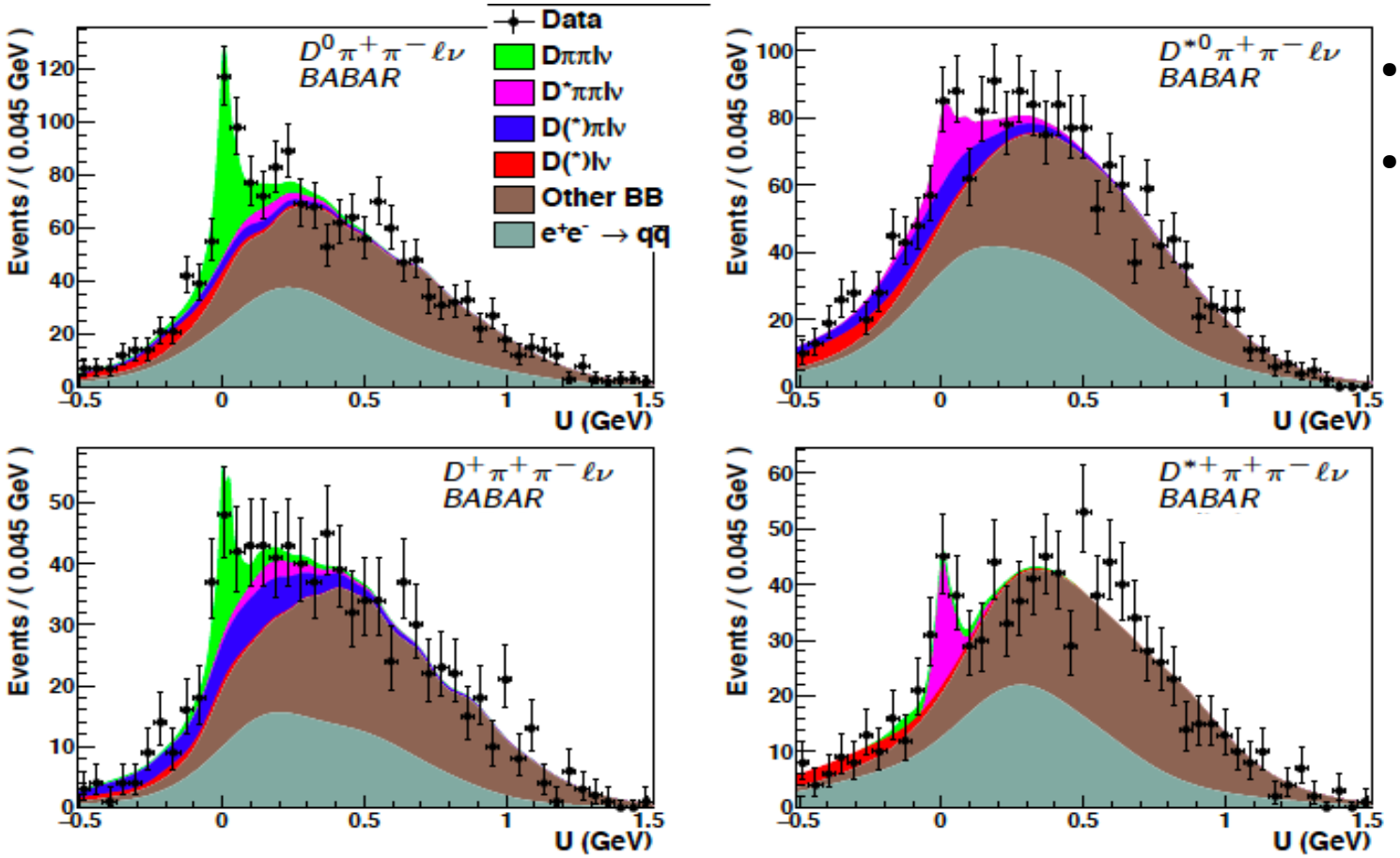
$\rho(770) \rightarrow$



Missing modes in the $B \to X_c \ell \nu$?

- Gap between inclusive $B \to X_c \ell \nu$ sum of known exclusive decays
- It is not $B \to D_s K(*) \ell \nu$: BF($B \to D_s K(*) \ell \nu$) =0.061 ± 0.010 %
- Good candidates: $B \to D^{(*)} \pi\pi(X) \ell \nu$ (what about $B \to D^{(*)} \eta \ell \nu$?)
  - 3-body decays from 1P states studied hadronically
    - Only D_1 has been observed, what about broad resonances?
  - Beyond 1P state: 2S or 1D?
- Non-resonant contribution? Belle & BaBar consistent with null hypothesis
  - Goity-Roberts model of SL 4-body decay predicts a softer lepton spectrum. It doesn't seems consistent with the missing component from the inclusive lepton spectrum

$B \to D^{(*)}\pi\pi\ell\nu$ in hadronic tagged events



- Unbinned ML fit
- Fit only the yields (shapes from MC templates)
  - Normalization channels
    - $B \to D^{(*)}\ell\nu$
  - Control channel
    - $B \to D^{(*)}\pi^{\pm}\ell\nu$

$$U = E_{miss} - |\vec{p}_{miss}|$$

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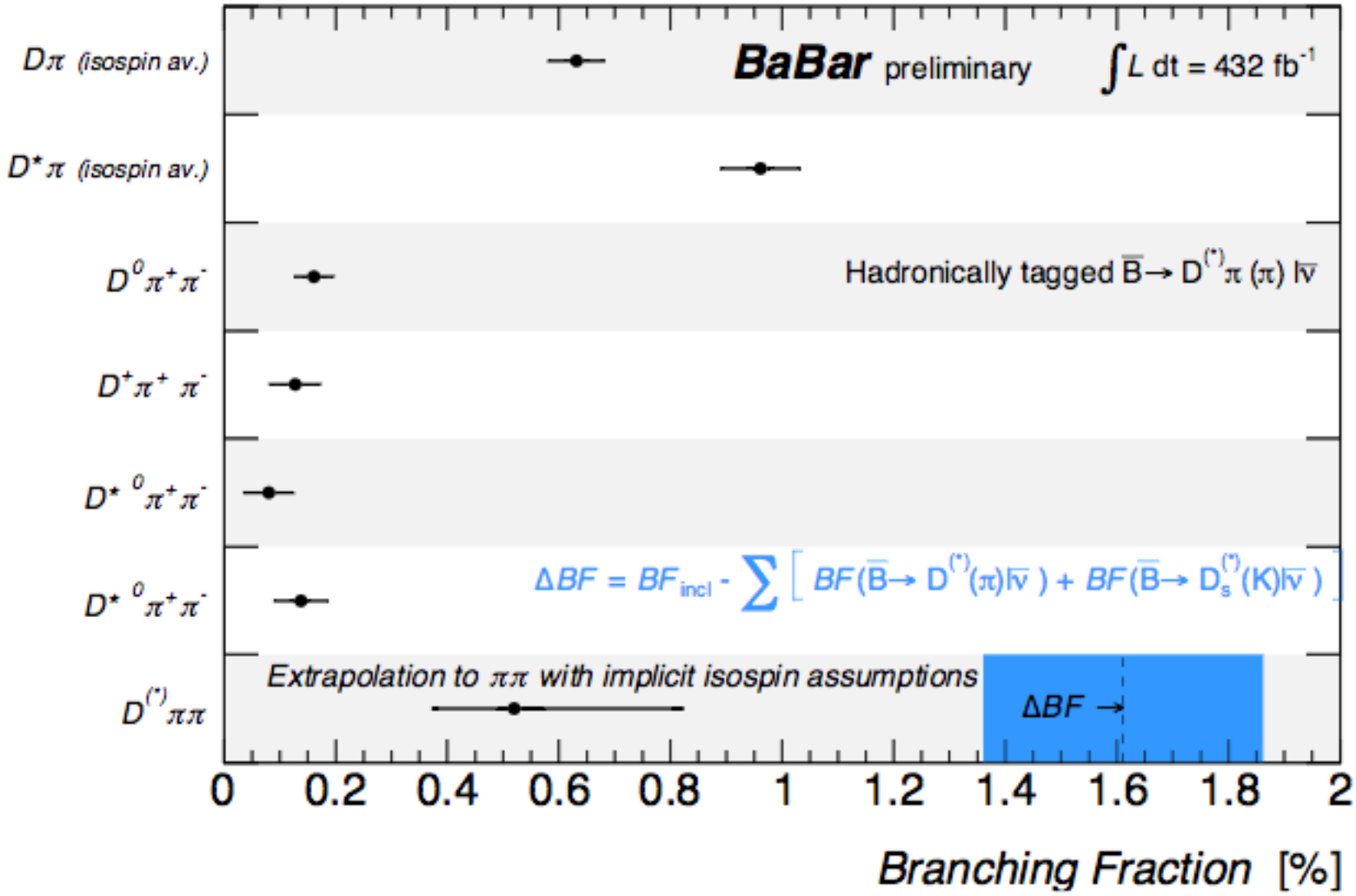
Channel	$R^{(*)}_{\pi^+\pi^-} \times 10^3$	$\mathcal{B} \times 10^5$
$D^0\pi^+\pi^-\ell^-\overline{\nu}$	$71 \pm 13 \pm 8$	$161 \pm 30 \pm 18 \pm 8$
$D^+\pi^+\pi^-\ell^-\overline{\nu}$	$58 \pm 18 \pm 12$	$127 \pm 39 \pm 26 \pm 7$
$D^{*0}\pi^+\pi^-\ell^-\overline{\nu}$	$14 \pm 7 \pm 4$	$80 \pm 40 \pm 23 \pm 3$
$D^{*+}\pi^+\pi^-\ell^-\overline{\nu}$	$28 \pm 8 \pm 6$	$138 \pm 39 \pm 30 \pm 3$
$D\pi^+\pi^-\ell^-\overline{\nu}$	$67 \pm 10 \pm 8$	$152 \pm 23 \pm 18 \pm 7$
$D^*\pi^+\pi^-\ell^-\overline{\nu}$	$19 \pm 5 \pm 4$	$108 \pm 28 \pm 23 \pm 4$

Status of the “gap”



- gap reduced from $\approx 7\sigma$ to $\approx 3\sigma$

extrapolation to full $\mathcal{B}$ assumed $\Gamma(D^{(*)}\pi^+\pi^-\ell\nu)/\Gamma(D^{(*)}\pi\pi\ell\nu) = 0.50 \pm 0.17$

From T.Lueck @EPS2015

Summary

- $B \to D\ell\nu$: measured quite well, limited only by statistics
- $B \to D^*\ell\nu$: new measurements would be desirable, BaBar and Belle data could still be fully exploited and LHCb has huge statistics!
  - For $|V_{cb}|$ extraction crucial to have model indipendent fits (BGL): published data cannot be refitted
  - For model of background, existing CLN fits describes the high statistics BaBar and Belle extremely well, regardless of meaning of R_1,R_2 and ρ^2
- $B \to D^{**}\ell\nu$: More measurements are needed: both BaBar and Belle have improved hadronic B tagging, LHCb can give crucial contributions as well
  - Narrow resonances well established: more FF measurements are needed!
  - Broad states are cloudy: 1/2 vs 3/2, Belle D_0^*>> D_1'
  - In $(c\bar{s})$ systems the ½ states are narrow: could it be possible to shed light on D_0^* and D_1' in SL decays from corresponding D_{s0}^* and D_{s1}' ?
  - More studies of $B \to D^{(*)}\pi\pi(X)\ell\nu$ would be needed!
    - Study of $D^{(*)}\pi\pi$ would allow to reduce systematics!

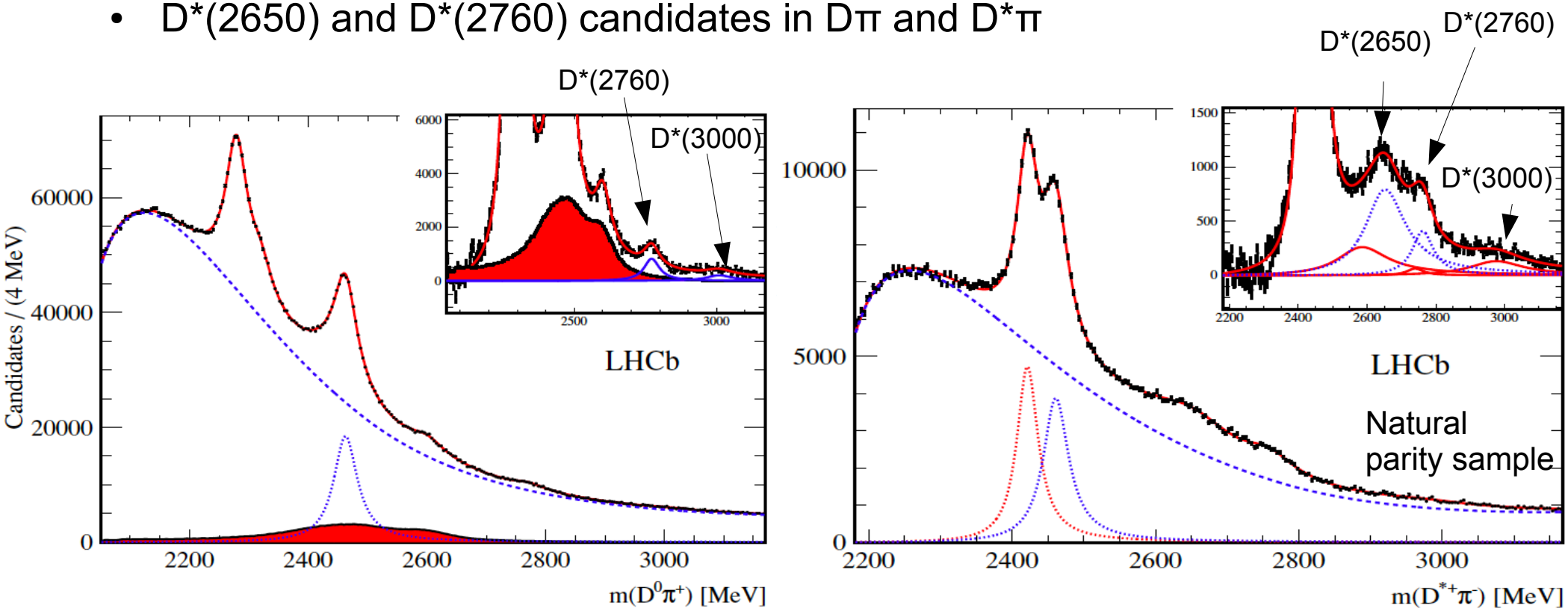
Modes	Width	*Dominant X_c mode*
D_s	-	$KK\pi$
D_s^*	-	$D_s\,\gamma$
$D_{s0}^*(2317)$	-	$D_s\,\pi^0$
$D_{s1}(2460)$	-	$D_s^*\,\pi^0$
$D_{s1}'(2536)$	1 MeV	$D^*\,K$
$D_{s2}^*(2573)$	17 MeV	$D^0\,K$

Backup

D_J from inclusive $pp \to D_J X$

JHEP09 (2013), 245

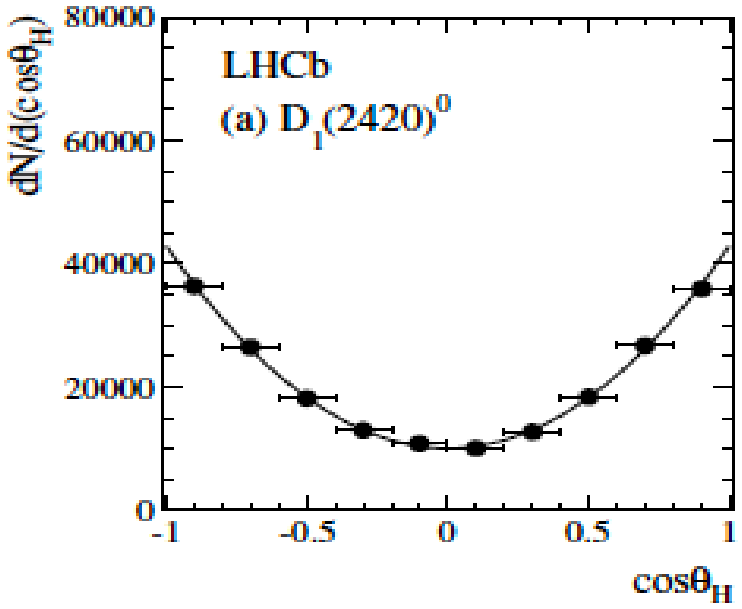
- Several new states observed in inclusive $D\pi$ and $D^*\pi$
  - $D^*(2650)$ and $D^*(2760)$ candidates in $D\pi$ and $D^*\pi$

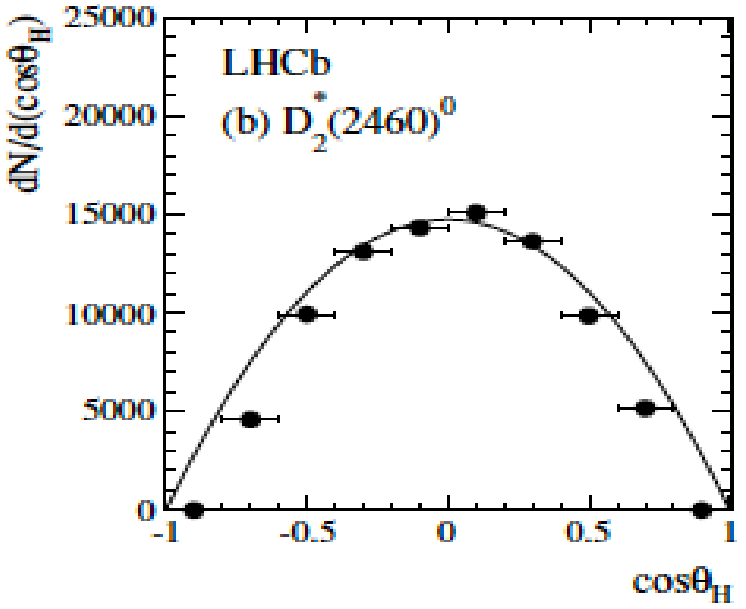


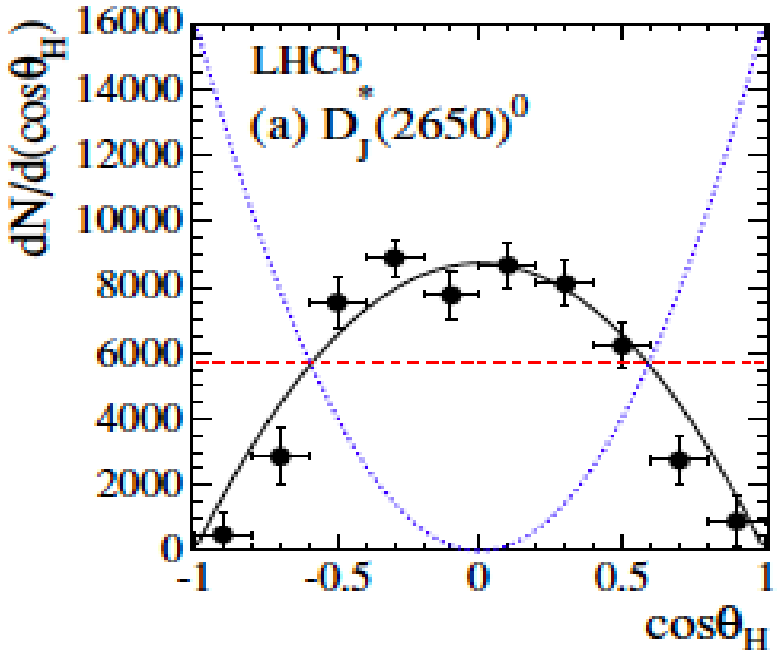
- From helicity angle distribution and decay mode:
  - Natural Parity: $J^P = 0^+, 1^-, 2^+, 3^-, \ldots$
  - Unnatural Parity: $J^P = 0^-, 1^+, 2^-, 3^+, \ldots$

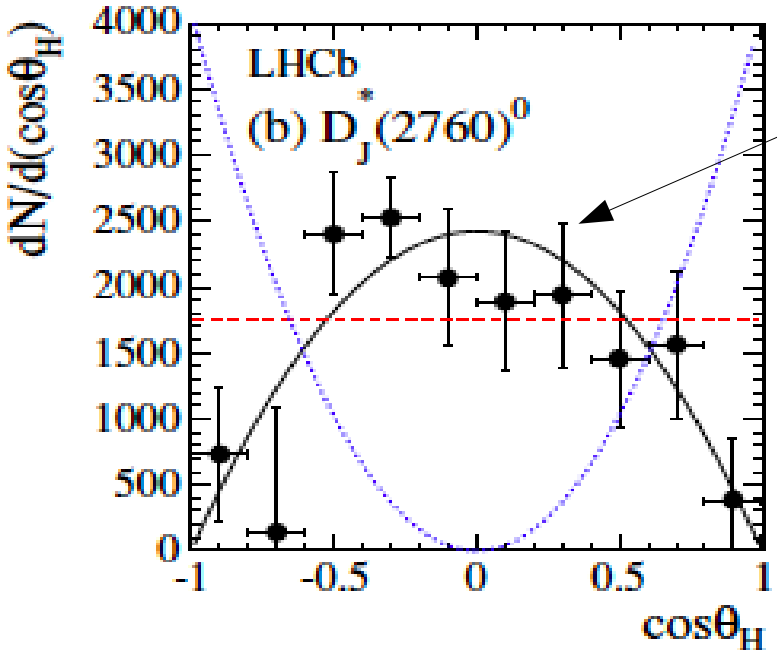
J^P assignment is not unique

D_J from inclusive $pp \to D_J X$





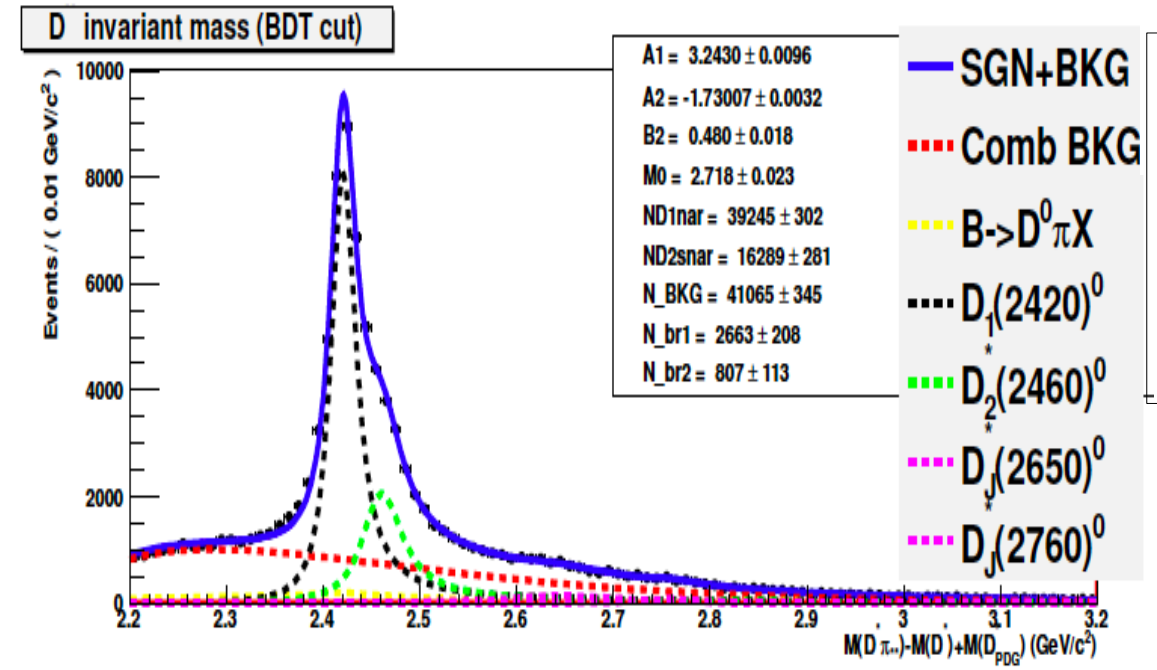


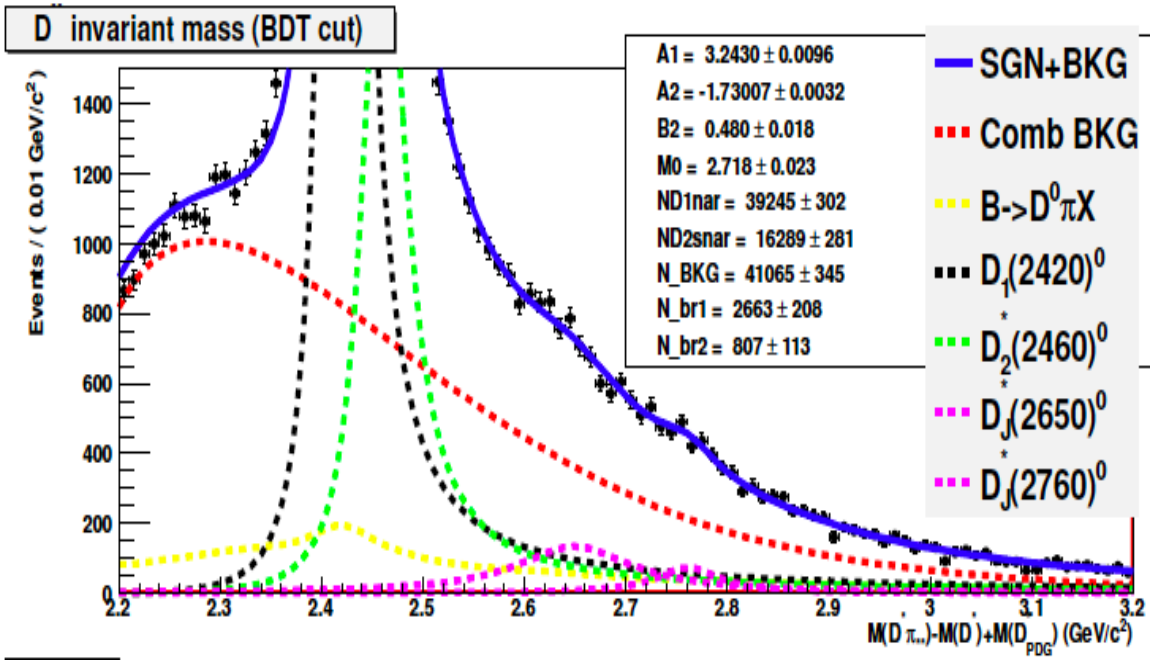


Natural parity Function

LHCb on D** in semileptonic decays?

From V. Battista
Master Thesis





$$\mathcal{B}(B \to D_1(2420)^0(\to D^*\pi_{**})\mu\nu_\mu X) = (0.151 \pm 0.002_{stat} \pm 0.022_{syst})\%$$
$$\mathcal{B}(B \to D_2^*(2460)^0(\to D^*\pi_{**})\mu\nu_\mu X) = (0.080 \pm 0.003_{stat} \pm 0.015_{syst})\%$$

$$\mathcal{B}(B \to D_J^*(2650)^0(\to D^*\pi_{**})\mu\nu_\mu X) = (1.16 \pm 0.09_{stat} \pm 0.21_{syst}) \cdot 10^{-4}$$
$$\mathcal{B}(B \to D_J^*(2760)^0(\to D^*\pi_{**})\mu\nu_\mu X) = (3.52 \pm 0.05_{stat} \pm 0.79_{syst}) \cdot 10^{-5}$$

D1(2420) is smaller than HFAG average
First observation of radial excitation
States in semileptonic B decays ?

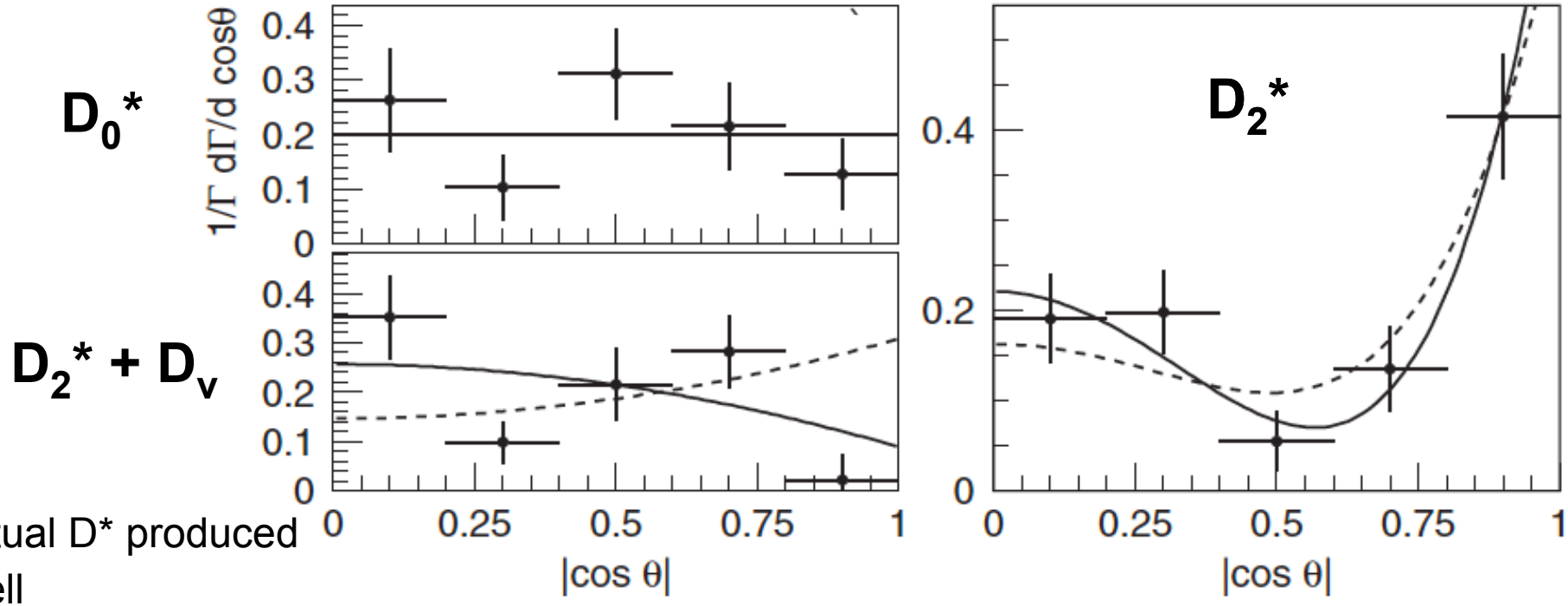
The analysis should be repeated taking into account also the helicity angle to increase sensitivity

Solid prediction 3/2 >> 1/2

PRD77,091503(2008)

- Both BaBar and Belle include the possibility for a non-resonant D(*)π component finding a rate consistent with zero
- A study of the helicity distribution can be used to confirm if the fitted broad component is consistent with the expected quantum numbers
- Belle reports the helicity study for D_2^* and D_0^*
  - Statistics is small but the predictions seems confirmed

Similar for BaBar (unpublished)



D_v: virtual D* produced off-shell

Exclusive-Inclusive "gap" (BF refer to B^+)

D	2.29 ± 0.10
D*	5.30 ± 0.12
D_0^*	0.44 ± 0.08 (?)
D_1'	0.19 ± 0.05 (?)
D_1	0.71± 0.08
D_2^*	0.30 ± 0.04
Σ	**9.23 ± 0.20**
X_c	**10.99 ± 0.16**
Σ-Xc	**1.76 ± 0.26%**

D	2.29 ± 0.10
D*	5.30 ± 0.12
Dπ	0.66 ± 0.08
D*π	0.87 ± 0.09
D_1 (Dππ)	0.29 ± 0.08
Σ	**9.41 ± 0.21**
X_c	**10.99 ± 0.16**
Σ-Xc	**1.58 ± 0.26%**

Semi inclusive are "non-controvertial"

Good agreements between Babar and Belle

[%]	*BABAR*
$B^+ \to D^- \pi^+ \ell^+ \nu_\ell$	0.42 ± 0.06 ± 0.03
$B^+ \to D^{*-} \pi^+ \ell^+ \nu_\ell$	0.59 ± 0.05 ± 0.04
$B^0 \to \bar{D}^0 \pi^- \ell^+ \nu_\ell$	0.43 ± 0.08 ± 0.03
$B^0 \to \bar{D}^{*0} \pi^- \ell^+ \nu_\ell$	0.48 ± 0.08 ± 0.04

[%]	*Belle*
$B^+ \to D^- \pi^+ \ell^+ \nu_\ell$	0.40 ± 0.04 ± 0.06
$B^+ \to D^{*-} \pi^+ \ell^+ \nu_\ell$	0.65 ± 0.08 ± 0.09
$B^0 \to \bar{D}^0 \pi^- \ell^+ \nu_\ell$	0.42 ± 0.07 ± 0.06
$B^0 \to \bar{D}^{*0} \pi^- \ell^+ \nu_\ell$	0.56 ± 0.21 ± 0.08