Complementary measurements for the upcoming high precision semitauonic campaign

GUY WORMSER
LAL, CNRS/IN2P3 , PARIS SACLAY UNIVERSITY

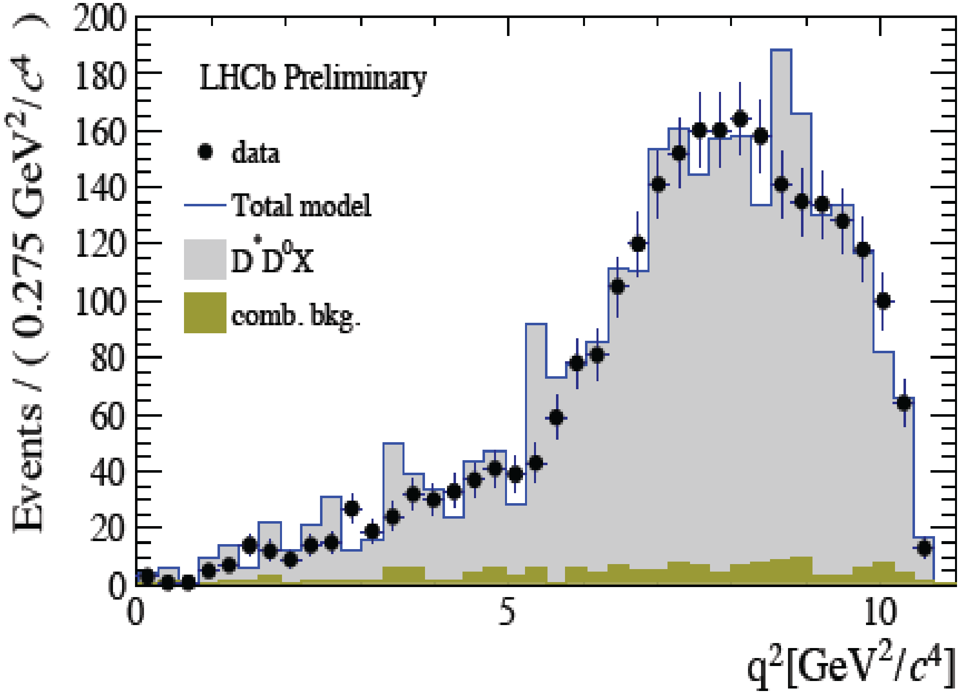
Rationale

- In 2018-2020, LHCb will publish its semitauonic RunII-based results. The statistical precision for the favoured modes (R(D*),R(D), R(Lc)) will be significantly below 5%
- ... To be followed by BELLE-II ......
- We must try to launch now an HEP-wide effort to measure all the important « bread-and-butter » measurements that play a significant role in the systematic uncertainty budget
- Some impact all R(D) measurements, some are quite specific..
- Some can be performed in several experiments, some only in a single one....
- Are not addressed here the measurements more directly related to R(X) such as R(D**), D*lnuX,...

$X_b \to D^* D^0 X$ control sample

- $X_b \to D^* D^0 X$ decays can be isolated by selecting exclusive $D^0 \to K^- 3\pi$ decays (kaon recovered using isolation tools).

- A correction to the q^2 distribution is applied to the simulation to match the data.



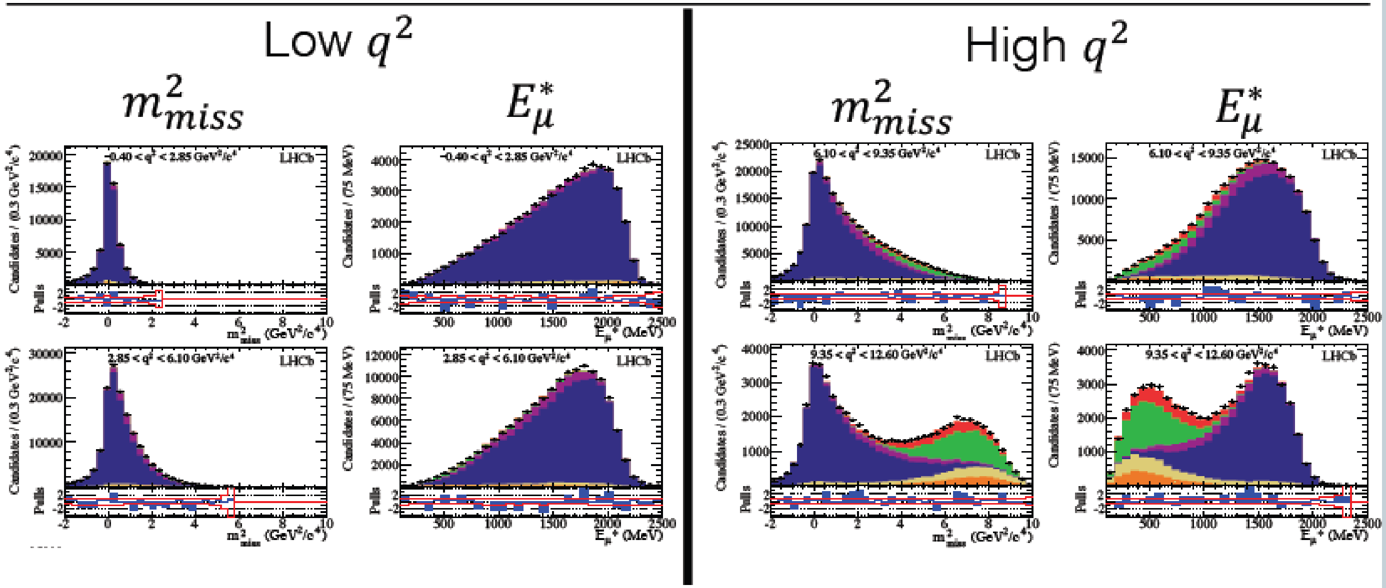
Measurements useful for all R(D) analysis

- Double charm decays
  - B➔D*(*) Ds(*,*,**)
    - Nice BABAR paper from 2006 using D* and $D_s^{(*)}$ recoils
    - What can be improved : more stats, higher mass range
  - Three-body B decays B➔D*DK
    - Important work from BABAR and BELLE to cover all these decays
    - What can be improved : more stats, D** states, K* states

LHCb muonic result (2015)

PRL 115 111803 (2015)

Fit Result



- Shown above: signal fit to "signal" data passing isolation selection
- Result $\frac{N_\tau}{N_\mu} = (4.32 \pm 0.37)\times10^{-2}$, $R(D^*) = 0.336 \pm 0.027 \pm 0.030$
- $N(\bar{B}^0 \to D^{*+}\mu^-\bar{\nu}_\mu) = 363{,}000 \pm 1600$

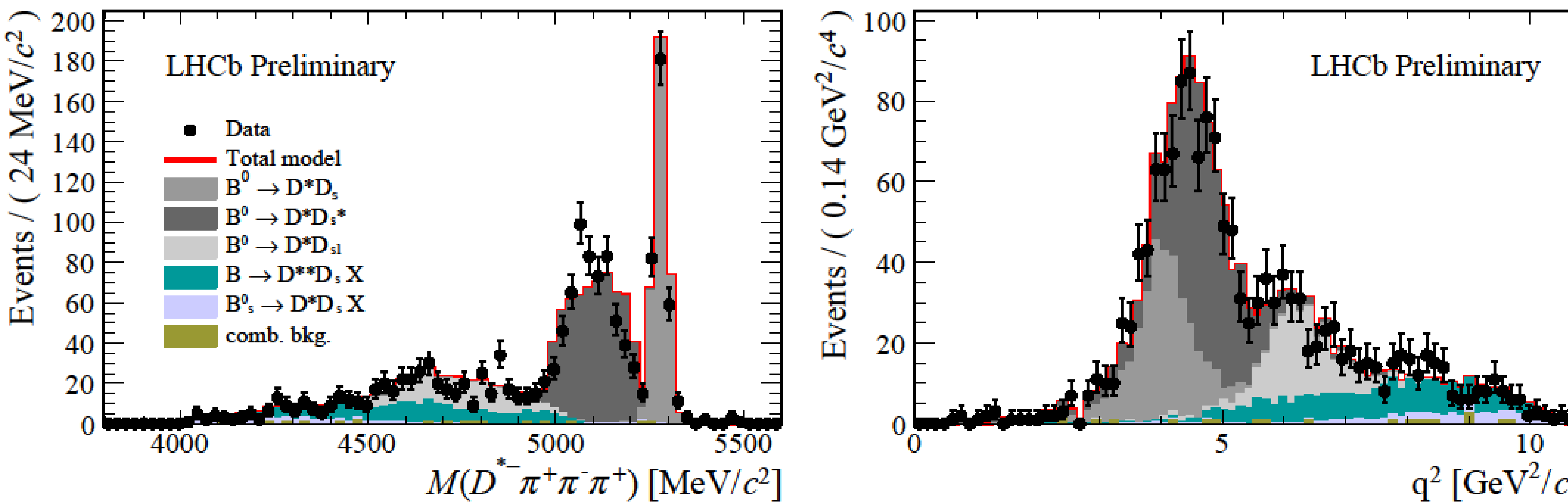
Data
$B \to D^*\tau\nu$
$B \to D^*H_c (\to l\nu X')X$
$B \to D^{**}l\nu$
$B \to D^*\mu\nu$
Combinatoric
Misidentified μ

Systematic uncertainties table

Contribution	Value %
Simulated sample size	4.7
Signal modeling	1.8
$D^{**}\tau\nu$ and $D_s^{**}\tau\nu$ feed-downs	2.7
$D_s^+ \to 3\pi X$ decay model	2.5
$B \to D^{*-}D_s^+X$, $B \to D^{*-}D^+X$, $B \to D^{*-}D^0X$ backgrounds	3.9
Combinatorial background	0.7
$B \to D^*3\pi X$ background	2.8
Empty bins in templates	1.3
Efficiency ratio	3.9
Total internal uncertainty	8.9
$\mathcal{B}(B^0 \to D^*3\pi)$ and $\mathcal{B}(B^0 \to D^*\mu\nu_\mu)$	4.5

D^*D_s+X events with reconstructed D_s in 3π

- Clear separation obtained of the D_s, D_s^* and D_s^{**} components
- Ratios ~1:2:2 (only 20% of D_s come directly from B)

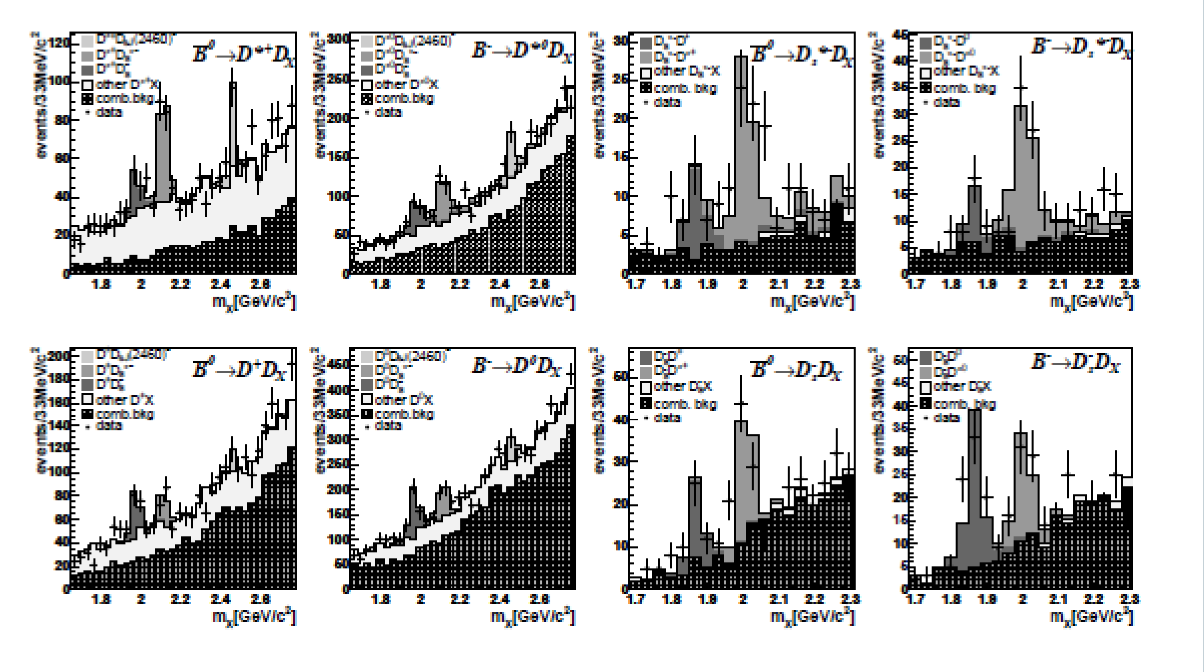


LHCb-PAPER-2017-017, arxiv 1708.08856

D* and D_s recoil study from BABAR

Study of $B \to D(*)D(*)$ (s(J)) Decays and Measurement of $D-s$ and DsJ (2460) Branching Fractions **Phys.Rev. D74 (2006) 031103**

. Only 205 fb-1
- Does not cover the higher mass regions for D_s** and D**



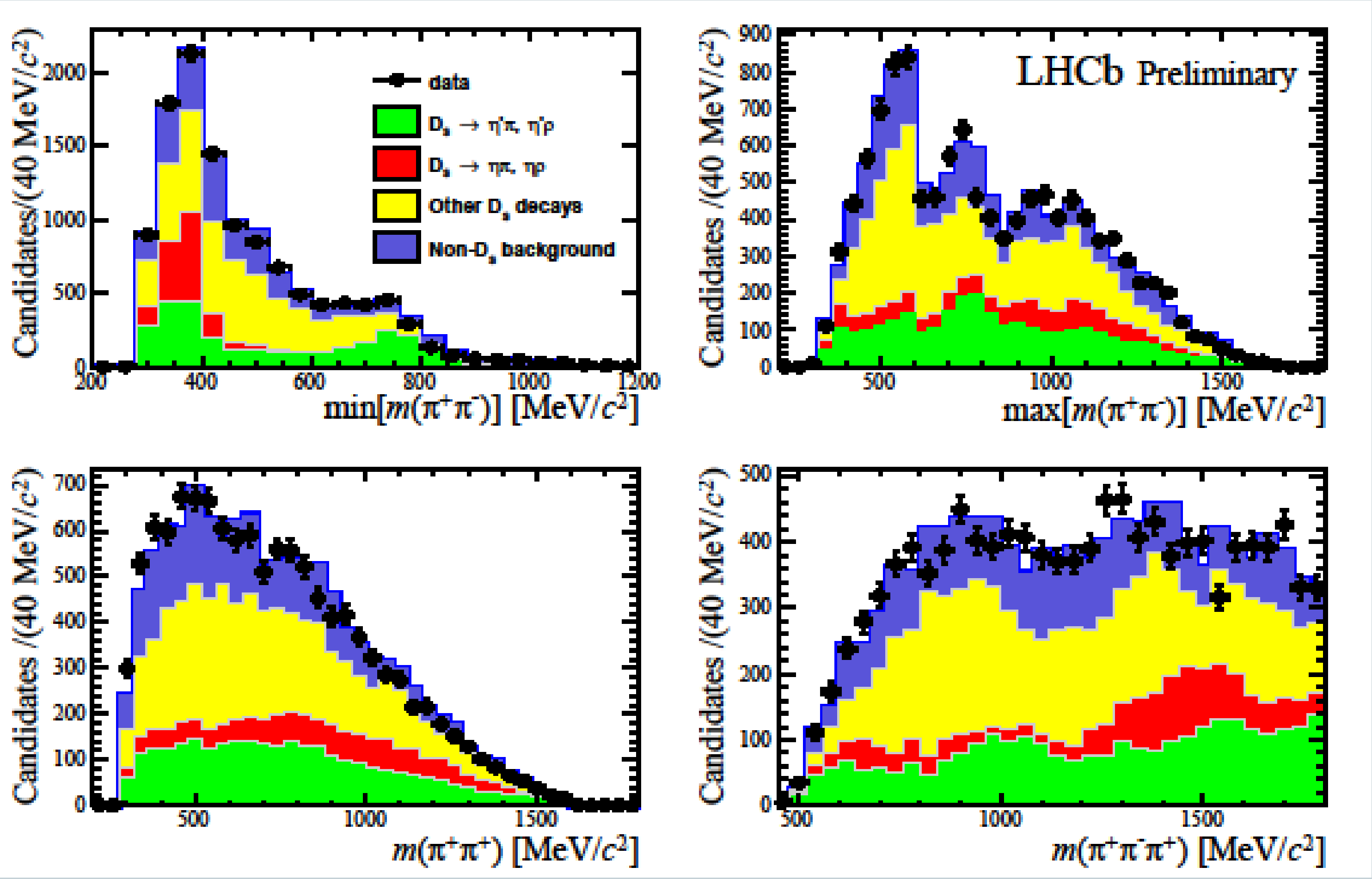
Physics of the B factories : Modes with K*, D** are missing
Precision at the 10% level

Mode	$\mathcal{B}$ (10^{-4})	Mode	$\mathcal{B}$ (10^{-4})
B decays through external W-emission amplitudes			
$B^0 \to D^- D^0 K^+$	$10.7 \pm 0.7 \pm 0.9$	$B^+ \to \overline{D}^0 D^+ K^0$	$15.5 \pm 1.7 \pm 1.3$
$B^0 \to D^- D^{*0} K^+$	$34.6 \pm 1.8 \pm 3.7$	$B^+ \to \overline{D}^0 D^{*+} K^0$	$38.1 \pm 3.1 \pm 2.3$
$B^0 \to D^{*-} D^0 K^+$	$24.7 \pm 1.0 \pm 1.8$	$B^+ \to \overline{D}^{*0} D^+ K^0$	$20.6 \pm 3.8 \pm 3.0$
$B^0 \to D^{*-} D^{*0} K^+$	$106.0 \pm 3.3 \pm 8.6$	$B^+ \to \overline{D}^{*0} D^{*+} K^0$	$91.7 \pm 8.3 \pm 9.0$
B decays through external+internal W-emission amplitudes			
$B^0 \to D^- D^+ K^0$	$7.5 \pm 1.2 \pm 1.2$	$B^+ \to \overline{D}^0 D^0 K^+$	$14.0 \pm 0.7 \pm 1.2$
$B^0 \to D^{*-} D^+ K^0$	$64.1 \pm 3.6 \pm 3.9$	$B^+ \to \overline{D}^0 D^{*0} K^+$	$63.2 \pm 1.9 \pm 4.5$
$+ D^- D^{*+} K^0$		$B^+ \to \overline{D}^{*0} D^0 K^+$	$22.6 \pm 1.6 \pm 1.7$
$B^0 \to D^{*-} D^{*+} K^0$	$79.3 \pm 3.8 \pm 6.7$	$B^+ \to \overline{D}^{*0} D^{*0} K^+$	$112.3 \pm 3.6 \pm 12.6$
B decays through internal W-emission amplitudes			
$B^0 \to \overline{D}^0 D^0 K^0$	$2.7 \pm 1.0 \pm 0.5$	$B^+ \to D^- D^+ K^+$	$2.2 \pm 0.5 \pm 0.5$
$B^0 \to \overline{D}^0 D^{*0} K^0$	$10.8 \pm 3.2 \pm 3.6$	$B^+ \to D^- D^{*+} K^+$	$6.3 \pm 0.9 \pm 0.6$
$+ \overline{D}^{*0} D^0 K^0$		$B^+ \to D^{*-} D^+ K^+$	$6.0 \pm 1.0 \pm 0.8$
$B^0 \to \overline{D}^{*0} D^{*0} K^0$	$24.0 \pm 5.5 \pm 6.7$	$B^+ \to D^{*-} D^{*+} K^+$	$13.2 \pm 1.3 \pm 1.2$

Specific measurements for LHCb-hadronic

- $D_s \rightarrow 3\pi X$ (probably better done at BES) but B-Factories could use a $B^0 \rightarrow D\, D_s(*)$ channel hadronic+SL Tag 2 M B^0 x0.10 D^*x0.03 D_s =6k D_s tagged (could also use $B^+ \rightarrow D^{*0}\, D_s$)
  - [similar to was done in 2006 for D_s to phi pi]
- $D^+ \rightarrow 3\pi X$ (probably better done at BES) but B-Factories could use $B^0 \rightarrow D^+ \pi$ (or 3π) (1.5Mx0.007)=10kD^+
- $B^0 \rightarrow D^*\, D_s$ (10% error right now) as a new normalization channel

The D_s decay model fit at low BDT
Half of the dataset used for this !!!



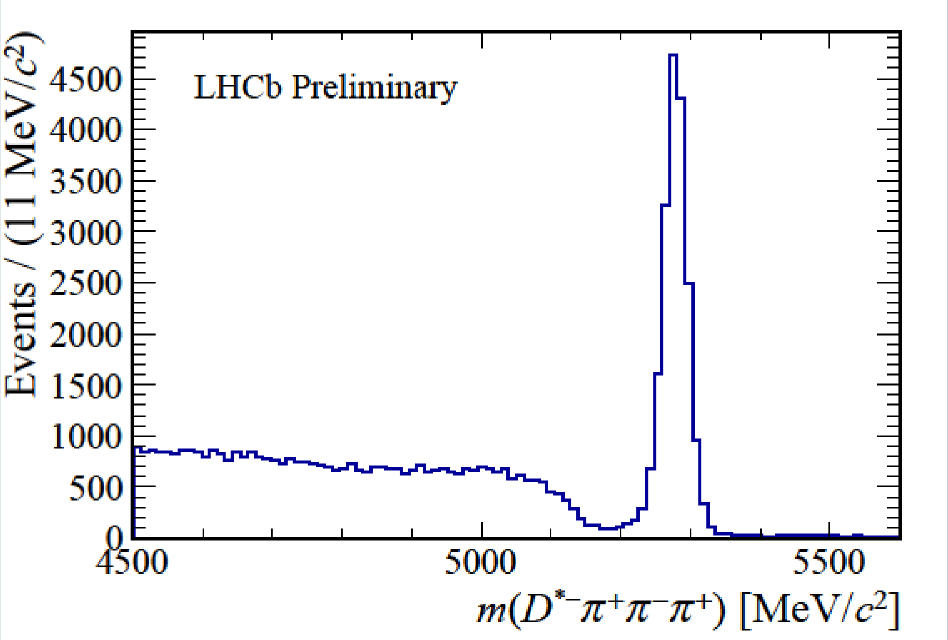
LHCb-PAPER-2017-017, arxiv 1708.08856

Importance of the normalization channel $B^o \rightarrow D^* 3\pi$

- Normalization mode as similar as possible to the signal to cancel production yield, BR uncertainties and systematics linked to trigger, PID, first selection cuts

Run 1, 3 fb^{-1}

17k events



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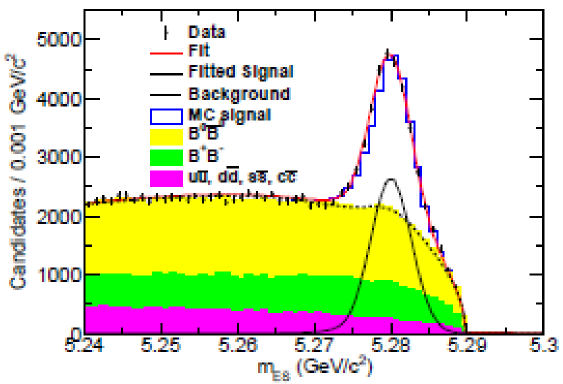
BABAR measurement of BR($B^o \rightarrow D^*3\pi$)

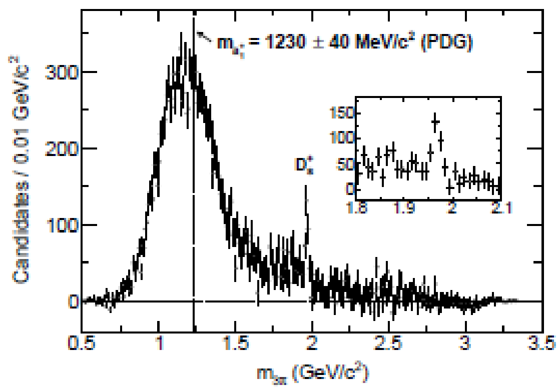
(Phys.Rev. D94 (2016), 091101)

- In PDG 2014 BR($B^o \rightarrow D^*3\pi$) known only to 11% precision ☹
- New BABAR analysis with full available statistics

BR($B^o \rightarrow D^*3\pi$)=
0,726±0.011±0.031)%

WA =(0,721±0.029)%
PDG 2017





There is also an LHCb result of $D^*3\pi/D^*\pi$ not included in the PDG
Phys. Rev. D87,092001 (2013)

Dominated by systematics errors
Good precision of 4.0 % now with the new WA !!

BELLE : Could you (re)measure this very precisely as well !!!

Source	Uncertainty (%)
Fit algorithm and peaking backgrounds	2.4
Track-finding	2.0
$\pi^+\pi^-\pi^+$ invariant-mass modeling	1.7
D^{*-} and $\overline{D}^0$ decay branching fractions	1.3
$\Upsilon(4S) \to B^0\overline{B}^0$ decay branching fraction	1.2
K^+ identification	1.1
Signal efficiency MC statistics	0.9
Sideband subtraction	0.7
$B\overline{B}$ counting	0.6
Total	4.3

Conclusion

- It will not be possible to benefit from the tantalizing statistical precision of upcoming round of semitauonic measurements (LHCb, BELLE-II) **without dedicated efforts on complementary measurements**
- I like to view this as a HEP-wide common effort to come to a final answer on the semitauonic NP hints
- Hottest topics on the list :
  - Two- and Three-body Double charm events
  - Inclusive D_s and D^+ decays to 3 pions