$B \to \tau\nu$ and $B \to D^{(*)} \tau\nu$ decays at BaBar

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Representing the BaBar collaboration

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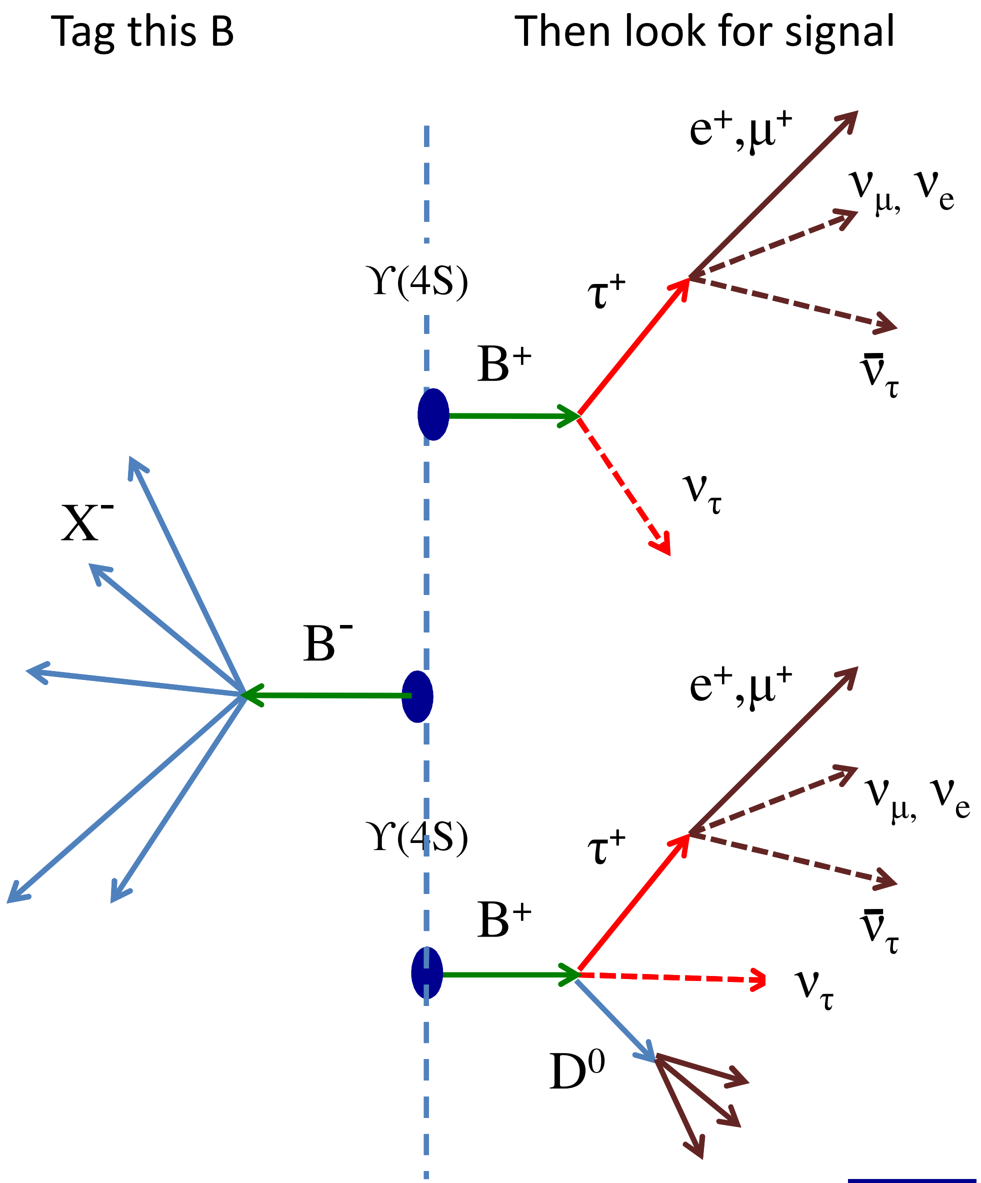
Tagging method

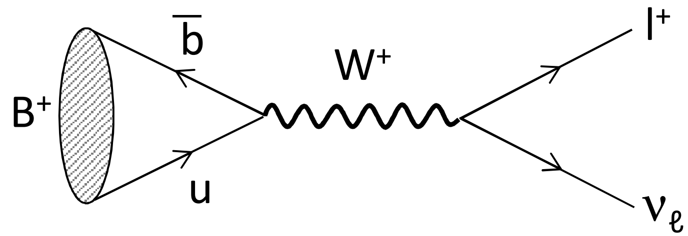
- Weak signal signature
  - Decay with missing momentum (many neutrinos in the final state)
  - Lack of kinematics constraints in final state
- background rejection improved reconstructing the companion B
- Look for signal in the rest of the event
  - Expect to find nothing more than visible signal decay products
  - No additional track and little activity in the calorimeter



Leptonic B decays

- B $\rightarrow$ lν very clean theoretically. SM uncertainty in the B decay constant f_B and |Vub| value.

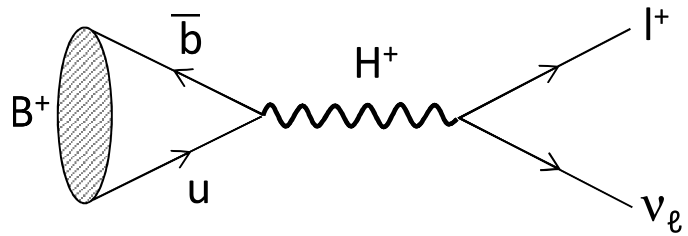
$$\mathcal{B}(B \to l\nu) = \frac{G_F^2 m_B}{8\pi} m_l^2 (1 - \frac{m_l^2}{m_B^2})^2 f_B^2 |V_{ub}|^2 \tau_B$$



- Interesting probe of physics beyond the SM, since also a charged Higgs can mediate the decay

$$\mathcal{B}(B \to l\nu)_{2HDM} = \mathcal{B}(B \to l\nu)_{SM} \times (1 - tan^2\beta \frac{m_B^2}{m_H^2})^2$$

$$\mathcal{B}(B \to l\nu)_{SUSY} = \mathcal{B}(B \to l\nu)_{SM} \times (1 - \frac{tan^2\beta}{1 + \epsilon_0 tan\beta} \frac{m_B^2}{m_H^2})^2$$



- B $\rightarrow$ τν used in global UT fits. B $\rightarrow$ μν out of reach of current B-factories

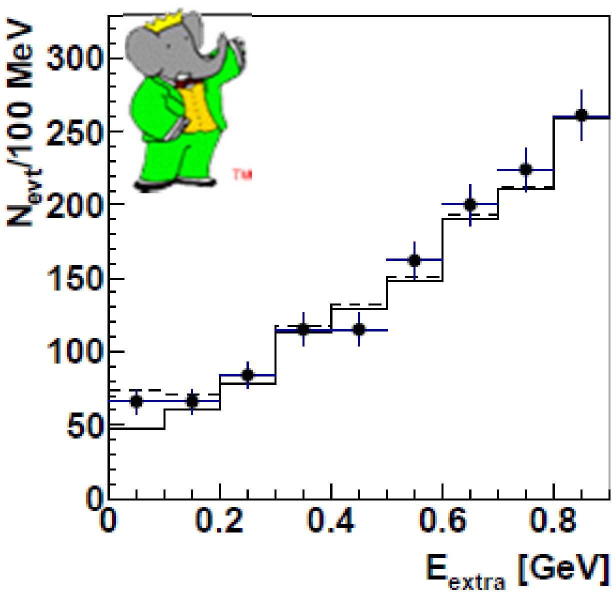
B → τν with hadronic tags at BaBar

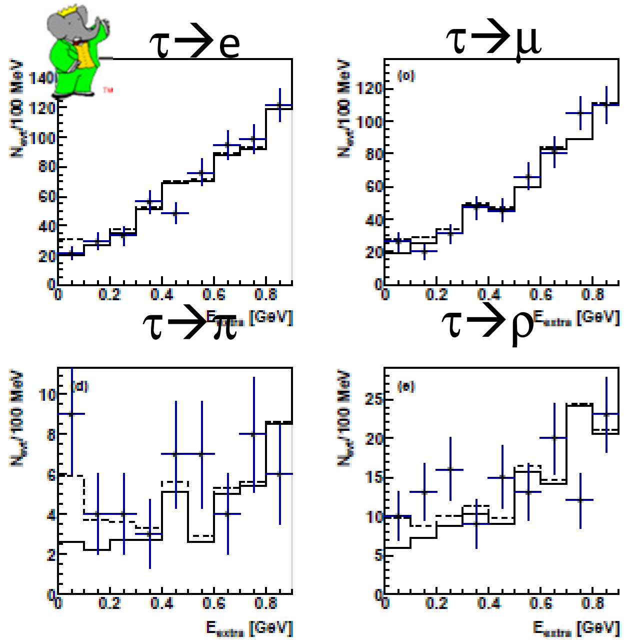
- Fit to residual energy in calorimenter simultaneously in 4 reconstructed modes (τ →eνν, τ →μνν, τ →πν, τ →ρν)
- Floating parameters: BF and 4 background yields
- Combinatorial B tag background estimated from data. B^+ background shape from MC
- Excess of events over background of 3.8 σ

arXiv:1207.0698[hep-ex]
Submitted to Phys.Rev.D (R)

MC modelling of signal E_{extra} PDF checked with double tags

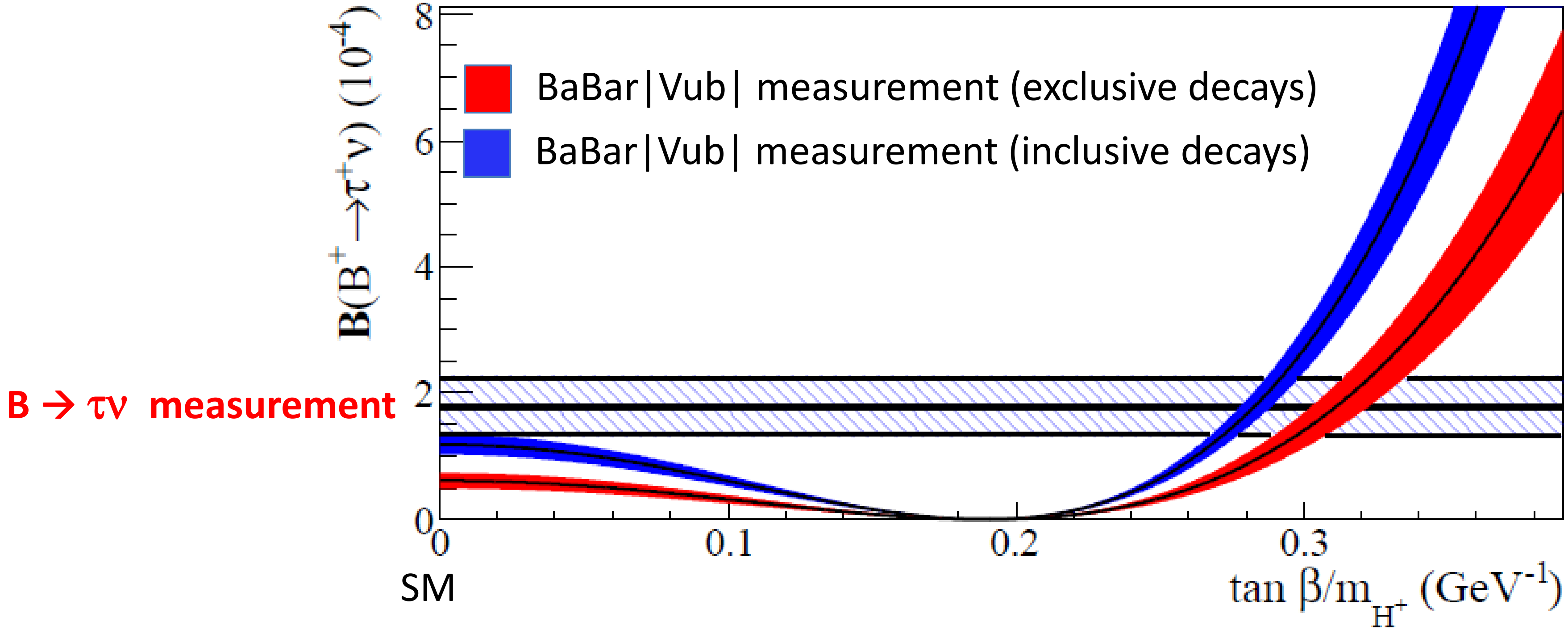
$$\mathcal{B}(B^+ \to \tau^+\nu) = (1.83^{+0.53}_{-0.49}(\text{stat.}) \pm 0.24(\text{syst.})) \times 10^{-4}$$





Comparison with the 2HDM type II

$$\mathcal{B}(B \to l\nu)_{2HDM} = \mathcal{B}(B \to l\nu)_{SM} \times (1 - tan^2\beta \frac{m_B^2}{m_H^2})^2$$

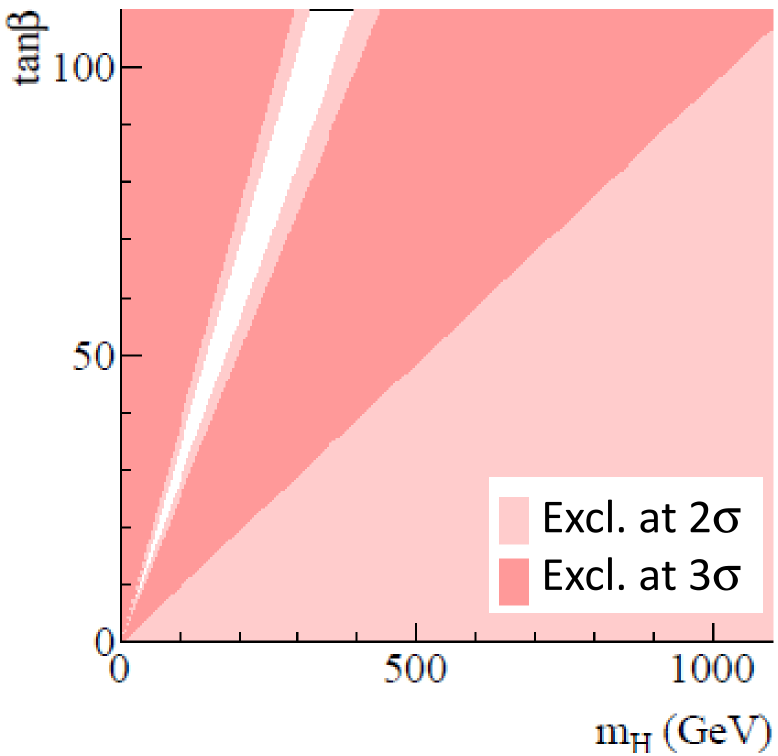


- Uncertainty in Standard Model prediction mostly due to $|V_{ub}|$
  $|V_{ub}|_{incl} = (4.33 \pm 0.28)\times10^{-3}$
  $|V_{ub}|_{excl} = (3.13 \pm 0.30)\times10^{-3}$ BABAR
  $f_B = (189 \pm 4)$ MeV (HPQCD arXiv:1202.4914)

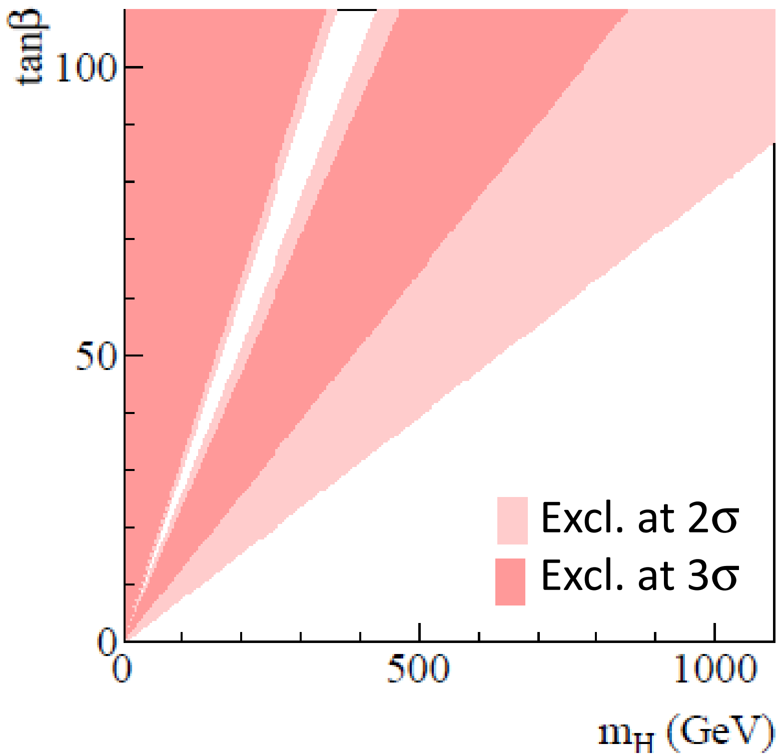
Constraints on the tan β vs m_{H^+} plane in 2HDM type II

Most of the parameter space of 2HDM is excluded at 90% C.L., if we assume exclusive $|V_{ub}|$ determination

90% C.L. exclusion for m_{H^+} up to 1 TeV at very high tan β (>70) using inclusive $|V_{ub}|$



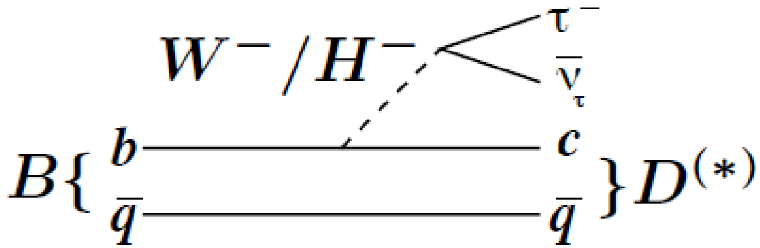
Exclusive $|V_{ub}|$



Inclusive $|V_{ub}|$

Ratio of B → D(*) τν to B → D(*) τν

- Semileptonic decays with a τ



$$\frac{d\Gamma_\tau}{dq^2} = \frac{G_F^2|V_{cb}|^2|\mathbf{p}|q^2}{96\pi^3 m_B^2}\left(1-\frac{m_\tau^2}{q^2}\right)^2\left[\left(|H_{++}|^2+|H_{--}|^2+|H_{00}|^2\right)\left(1+\frac{m_\tau^2}{2q^2}\right)+\frac{3}{2}\frac{m_\tau^2}{q^2}|H_{0t}|^2\right]$$

D* only

H^+ contr. here

- We test the SM measuring the ratios

$$R(D) = \frac{Br(\overline{B} \to D\tau\nu)}{Br(\overline{B} \to D\ell\nu)} \qquad R(D^*) = \frac{Br(\overline{B} \to D^*\tau\nu)}{Br(\overline{B} \to D^*\ell\nu)}$$

- SM predictions are R(D) = 0.297 ± 0.017 and R(D*) = 0.252 ± 0.003

Analysis strategy

- Full reconstruction of a tag B in hadronic decays.
- Identify e or μ and reconstruct a D meson (D^{*+}, D^{*0}, D^{+}, D^{0})
- Kinematic requirement: $q^2 > 4\ GeV^2$

arXiv:1205.5442[hep-ex]
Submitted to Phys.Rev.Lett.

- 2D likelihood fit to $M^2_{miss}=(P_{ee}-p_{tag}-p_D-p_l)^2$ and p^*_l

Yields floating

$B \rightarrow D\, l\, \nu$ normalization

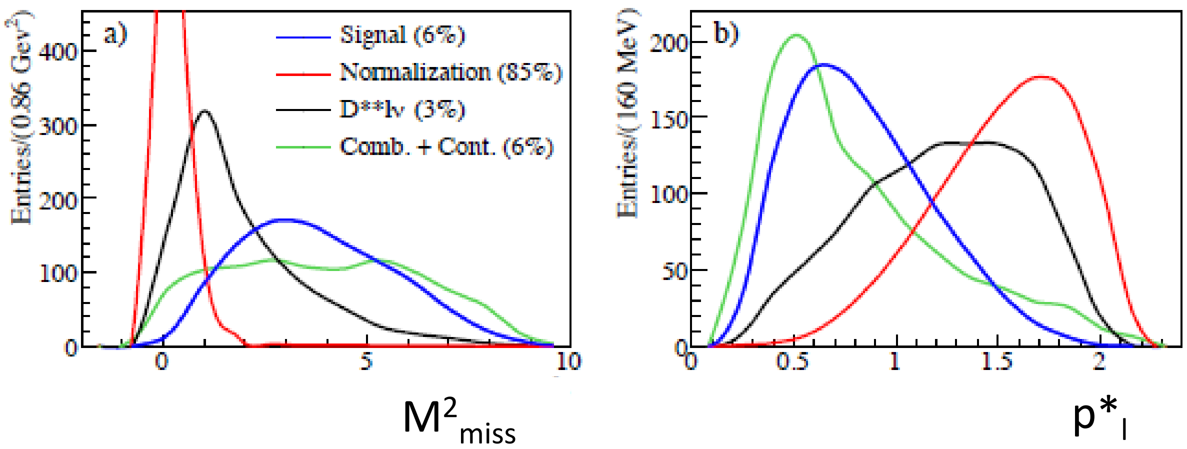
$B \rightarrow D\, \tau\nu$ signal

$B \rightarrow D^{**}\, l\, \nu$ background
(from a $D^{(*)}\, \pi^0\, l\, \nu$ CS)

Fixed parameters

BB combinatorial and continuum bkgs

cross-feeds among modes

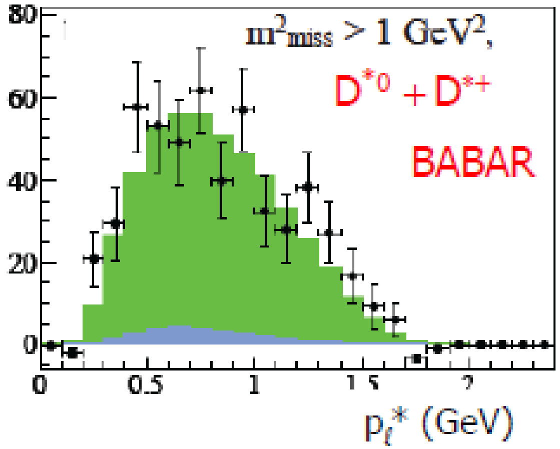


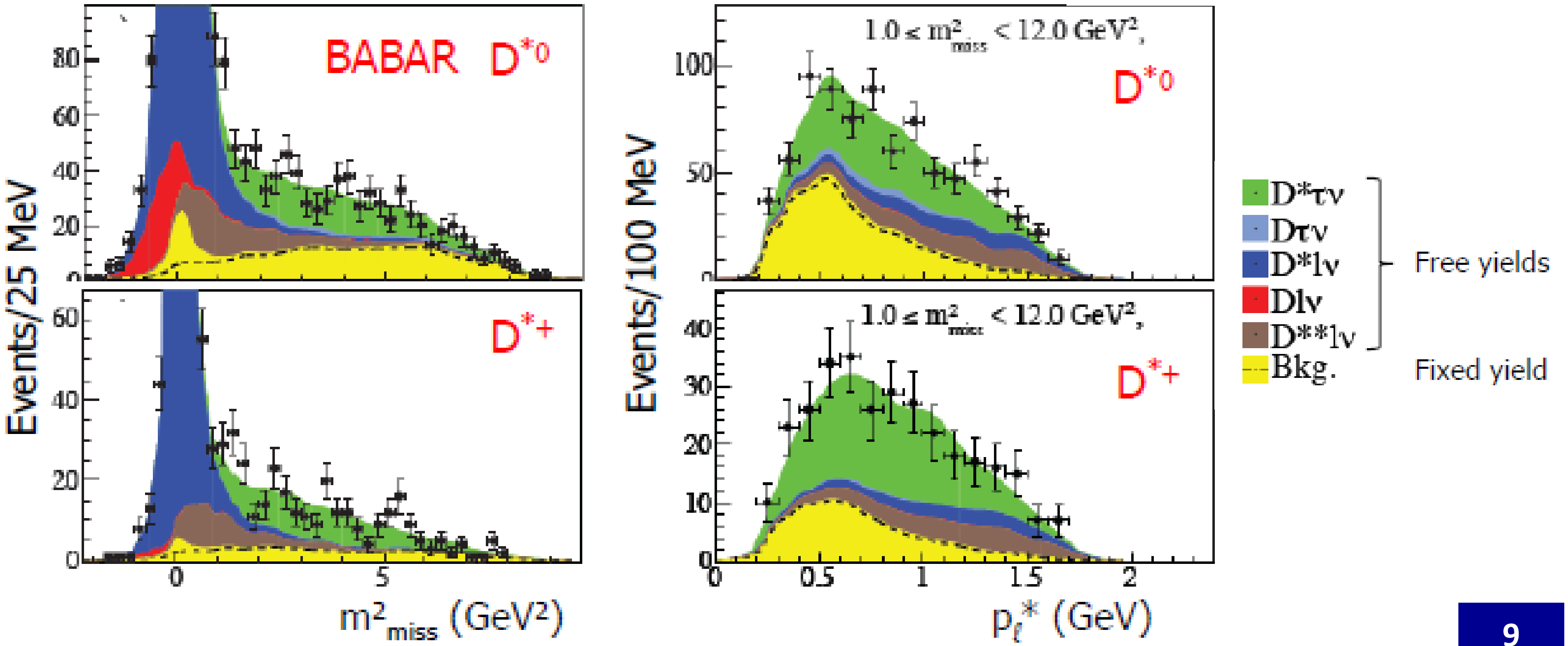
PDF taken from
Monte Carlo

$B \to D^* \tau \nu$ results

	$D^{*0}\tau\nu$	$D^{*+}\tau\nu$	$D^{*}\tau\nu$
N_{sig}	639 ± 62	245 ± 27	888 ± 63
Significance (σ)	11.3	11.6	16.4
$R(D^*)$	0.322 ± 0.032	0.355 ± 0.039	0.332 ± 0.024

Isospin constrained

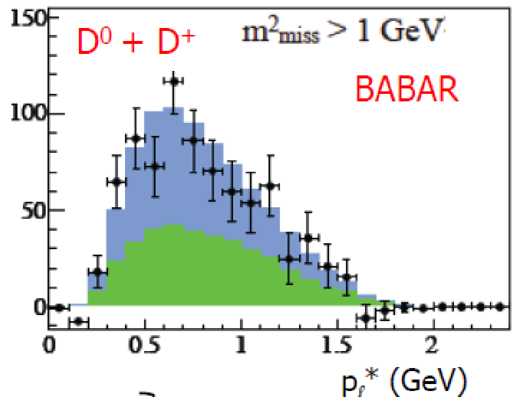


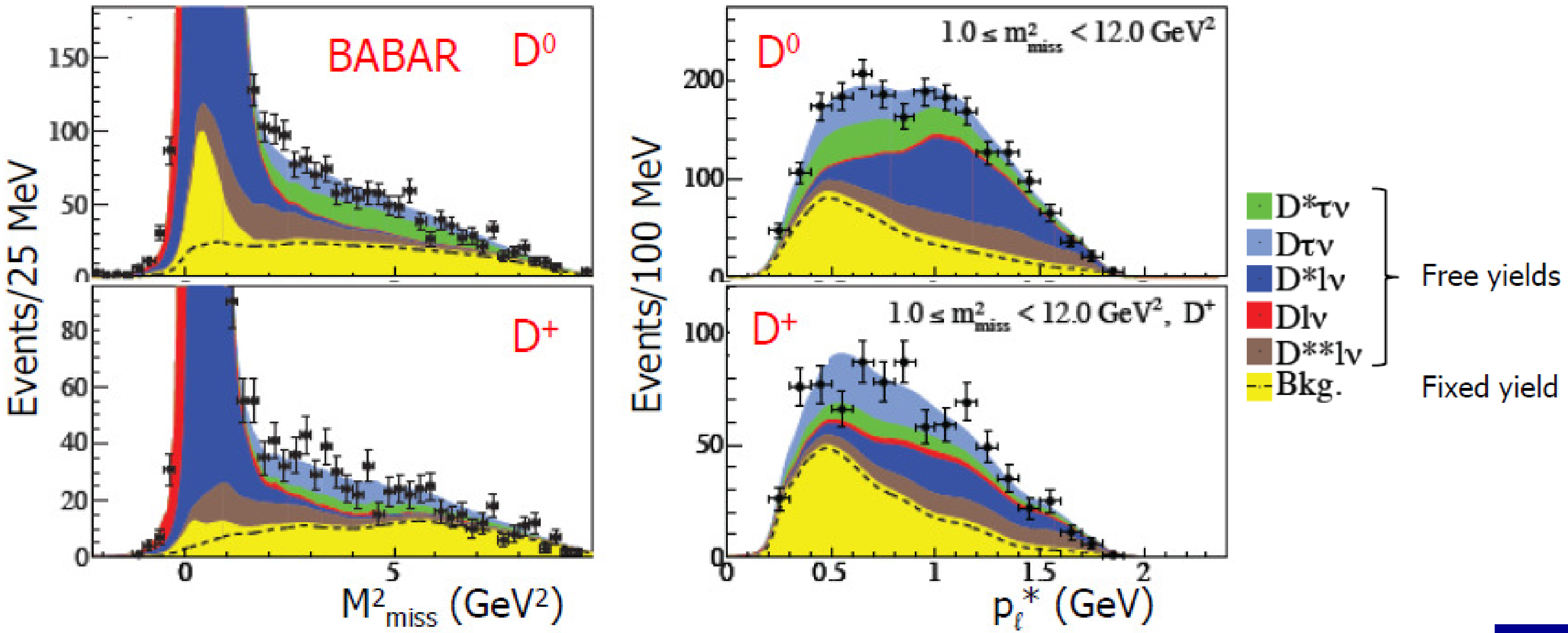


B → D τ ν results

	$D^0\tau\nu$	$D^+\tau\nu$	$D\tau\nu$
$N_{\rm sig}$	314 ± 60	177 ± 31	489 ± 63
Significance (σ)	5.5	6.1	8.4
$R(D)$	0.429 ± 0.082	0.469 ± 0.084	0.440 ± 0.058

Isospin constrained



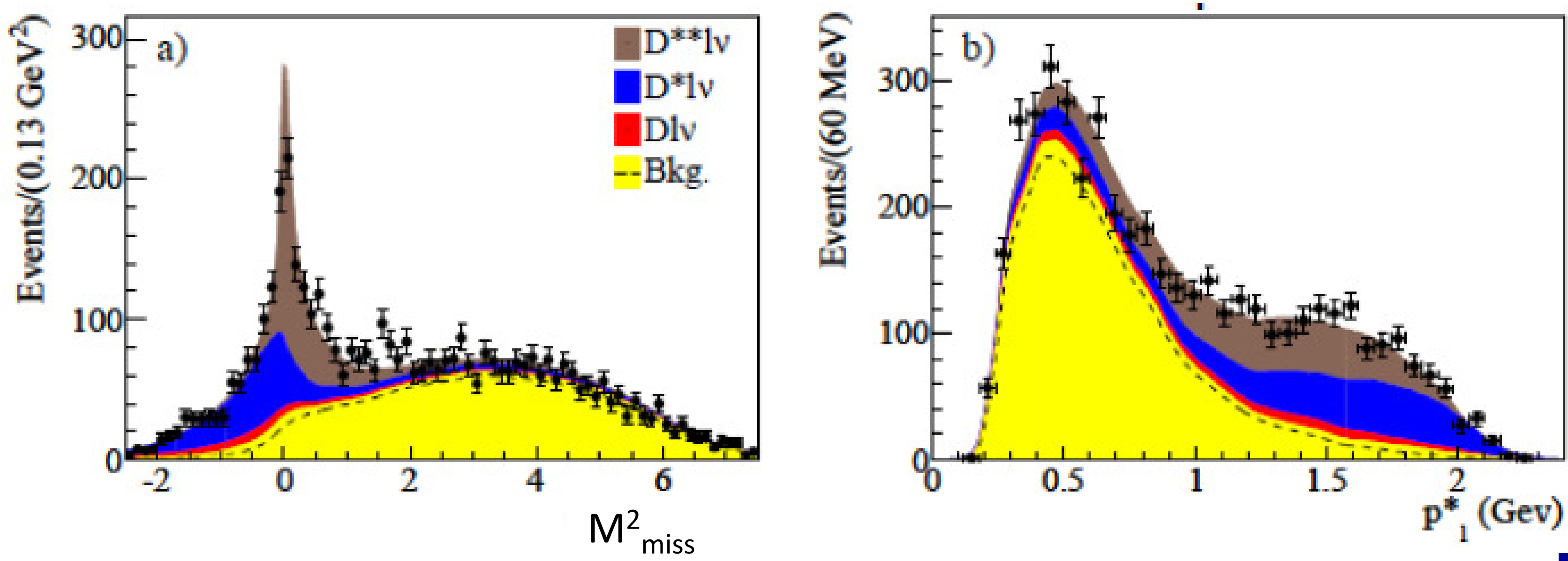


Systematic Uncertainties

- Main systematics uncertainties
  - D** background yield from a $D^{(*)}\pi^0 l \nu$ Data control sample
  - <u>Signal </u>MC statistic
    - For PDF extraction
  - BB and continuum background

Source	Uncertainty (%) $R(D)$	$R(D^*)$	ρ
$D^{**}\ell\nu$ background	5.8	3.7	0.62
MC statistics	5.0	2.5	-0.48
Cont. and $B\overline{B}$ bkg.	4.9	2.7	-0.30
$\varepsilon_{sig}/\varepsilon_{norm}$	2.6	1.6	0.22
Systematic uncertainty	9.5	5.3	0.05
Statistical uncertainty	13.1	7.1	-0.45
Total uncertainty	16.2	9.0	-0.27

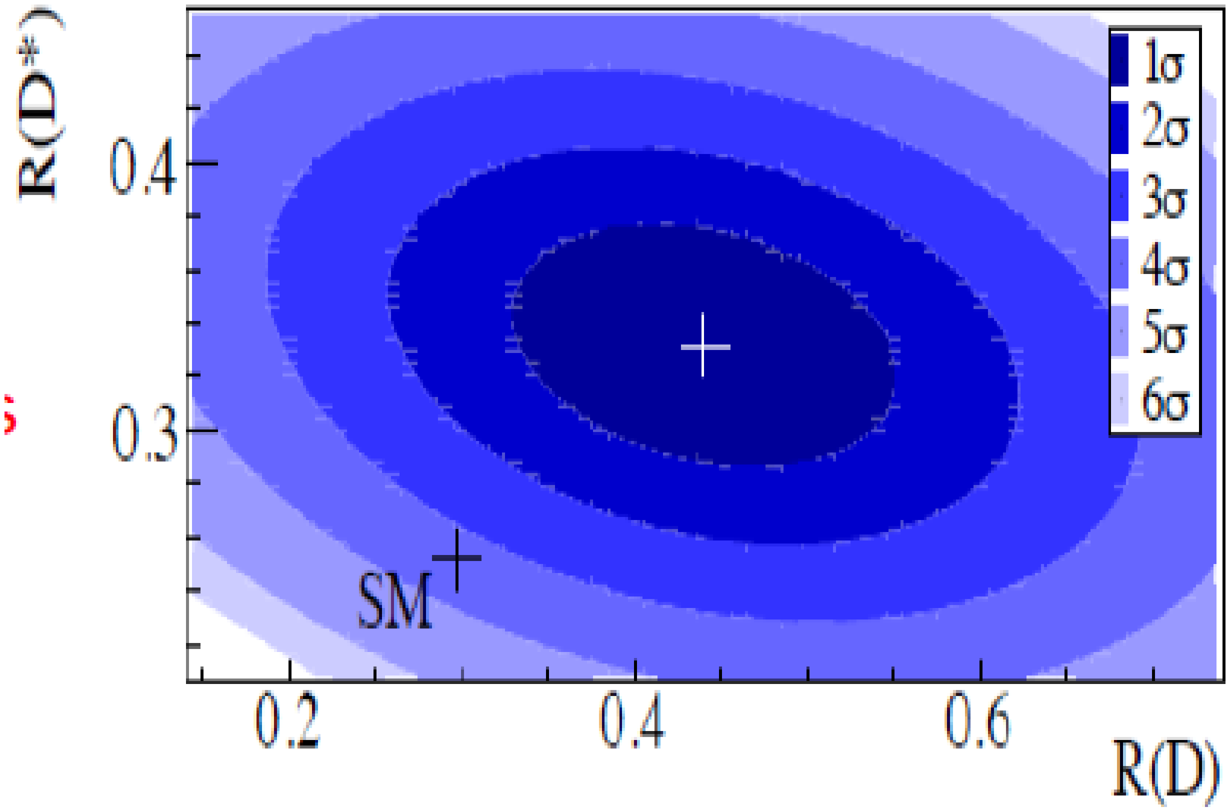
$D(*)\ \pi^0\ l\ \nu$ Control sample



Comparison with Standard Model

Z. Phys C46, 93 (1990)
PRD 82, 0340276 (2010)
PRD 85, 094025 (2012)
and recent updates

	R(D)	R(D*)
BABAR	0.440 ± 0.071	0.332 ± 0.029
SM	0.297 ± 0.017	0.252 ± 0.003
Difference	2.0 σ	2.7 σ



Combinination yields

χ^2 / n.d.o.f. = 14.6/2

(probability: 6.9×10^{-4})

3.4σ away from SM

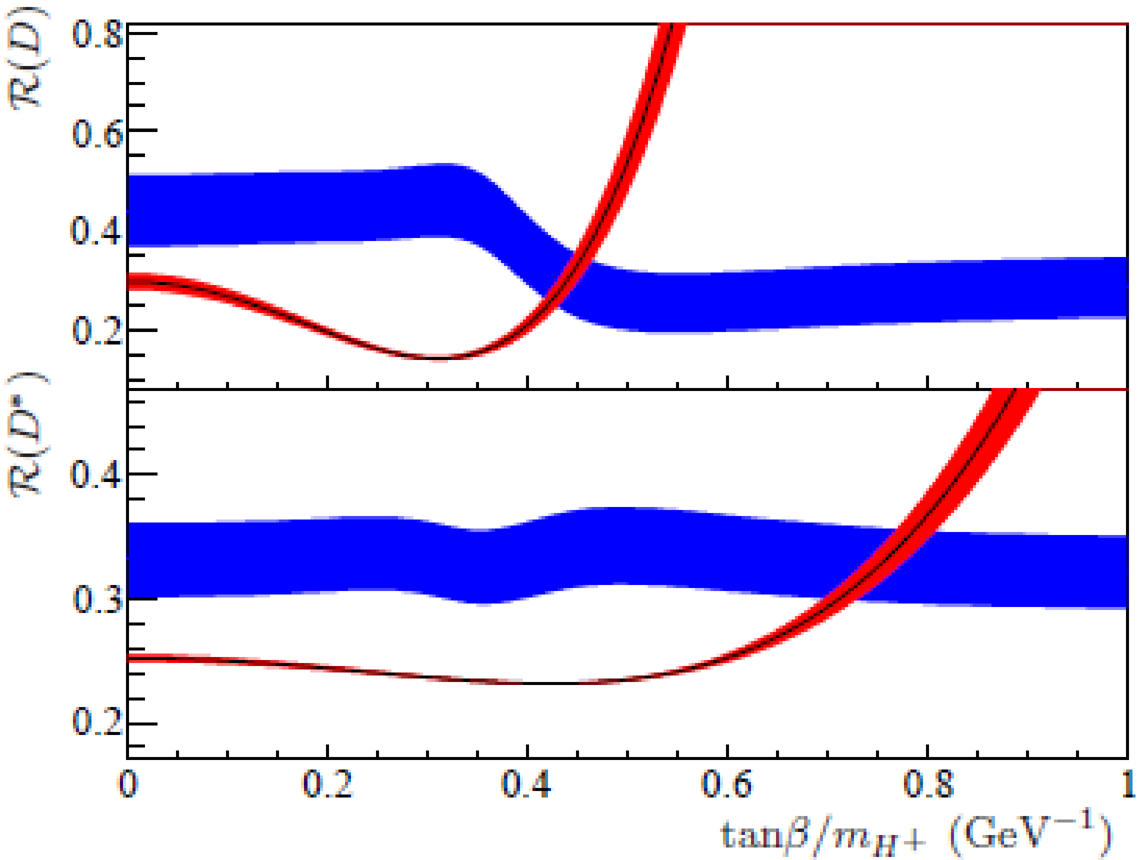
2HDM type II cannot explain the excess

- A Charged Higgs within 2HDM type II contribution:

$$H_t^{2\text{HDM}} = H_t^{\text{SM}} \times \left(1 - \frac{\tan^2\beta}{m_{H\pm}^2} \frac{q^2}{1 \mp m_c/m_b}\right)$$

- for $D\tau\nu$ PRD 78, 015006 (2008)

+for $D^*\tau\nu$ PRD 85, 094025 (2012)



Taking into account the effect of $\tan\beta/m_H$ on efficiency

R(D) → $\tan\beta/m_H = 0.44 \pm 0.02$

R(D*) → $\tan\beta/m_H = 0.75 \pm 0.04$

Mutually exclusive with CL >99.8%

Conclusions

- Updated result on $B \rightarrow \tau \nu$ with hadronic tagging

  $BF(B \rightarrow \tau \nu) = (1.8 \pm 0.5 \pm 0.2) \times 10^{-4}$.
  arXiv:1207.0698 [hep-ex], submitted to Phys.Rev.D (R)

  Agreement with the SM in tension using exclusive |Vub| measurements (2.4σ)
  Better agreement using inclusive |Vub| (1.6σ)

- Improved measurement of $R(D^{(*)}) = BF(B \rightarrow D^{(*)} \tau \nu) / BF(B \rightarrow D^{(*)} l \nu)$

  $R(D^*) = 0.332 \pm 0.024 \pm 0.018$ $R(D) = 0.440 \pm 0.058 \pm 0.042$

  exceeding the SM predicted values by $3.4\ \sigma$.

  arXiv:1205.5442[hep-ex], submitted to Phys.Rev.Lett.

- 2HDM type II (alone) cannot accomodate the results and theorists already at work building models