Heavy flavour meson decays with tau leptons in the final state at BaBar

- First measurements for $B \to K\tau\tau$ using Hadronic Tag Method
- Latest measurements for $B \to \tau\nu$ using Hadronic Tag Method

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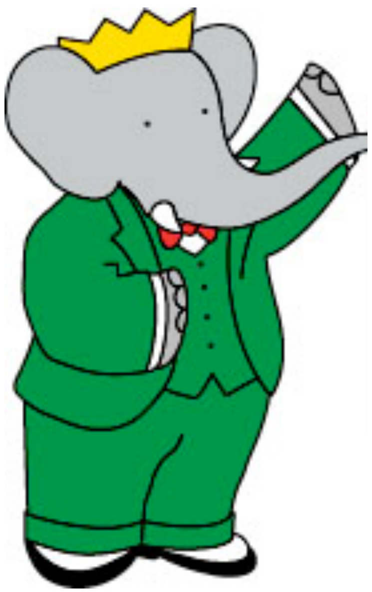
on behalf of the Babar Collaboration



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First measurements for $B \to K\tau\tau$ using Hadronic Tag Method

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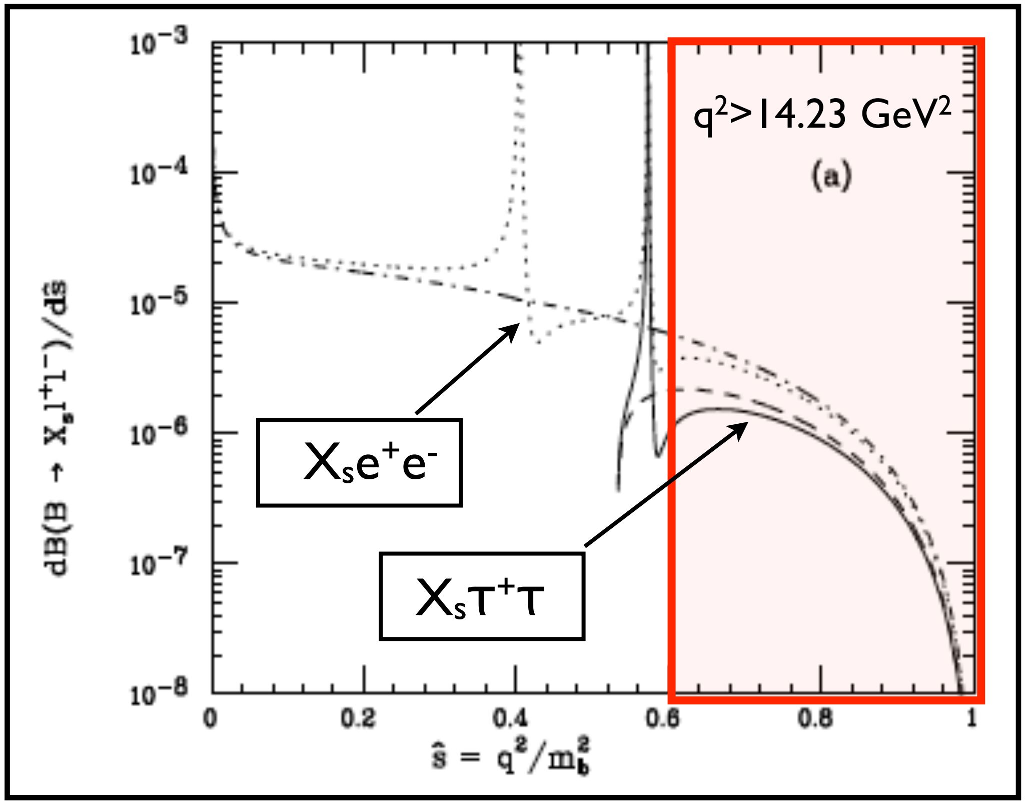
$B \to K\tau\tau$ Standard Model

✦$Br(B \to X_s\ \tau^+\tau^-)$ expected to be comparable to $Br(B \to X_s\ l^+l^-)$ in high q^2 region
✦Exclusive $B \to K\tau^+\tau^-$ predicted to be 50-60% of total inclusive rate, that is ~2×10^{-7}
✦With the $\Upsilon(4s)$ full Babar dataset we expect ~100 evts

ℓ	$0.6 \leq \hat{s} \leq 1$
e	8.5×10^{-7}
μ	8.5×10^{-7}
τ	4.3×10^{-7}

$\ell = \tau$ (solid and dashed curves) and $\ell = e$ (dotted and dash-dotted curves)



✦D. Du, C. Liu, and D. Zhang, "Rare decay Kτ+τ- in heavy meson chiral perturbation theory", Phys. Lett. B317, 179 (1993).
✦J. Hewett, "Tau polarization asymmetry in B -> X(s) tau+ tau-.", Phys. Rev. D53, 4964-4969 (1996)

B→Kτ⁺τ⁻ New Physics Contributions

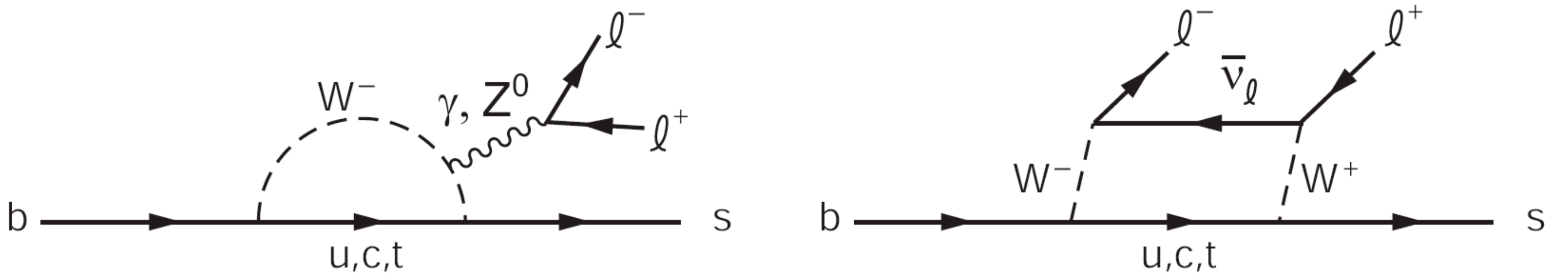
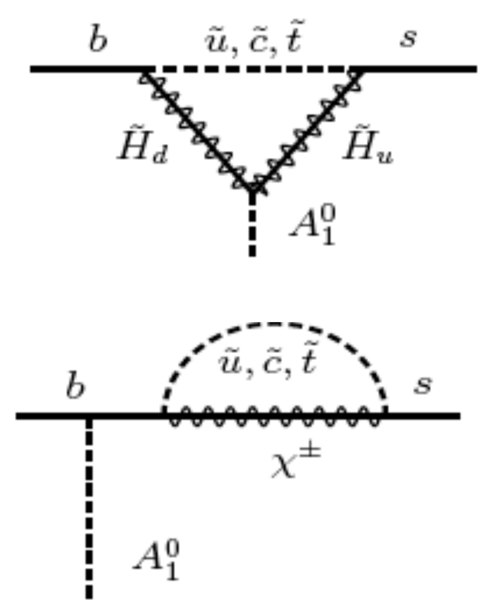


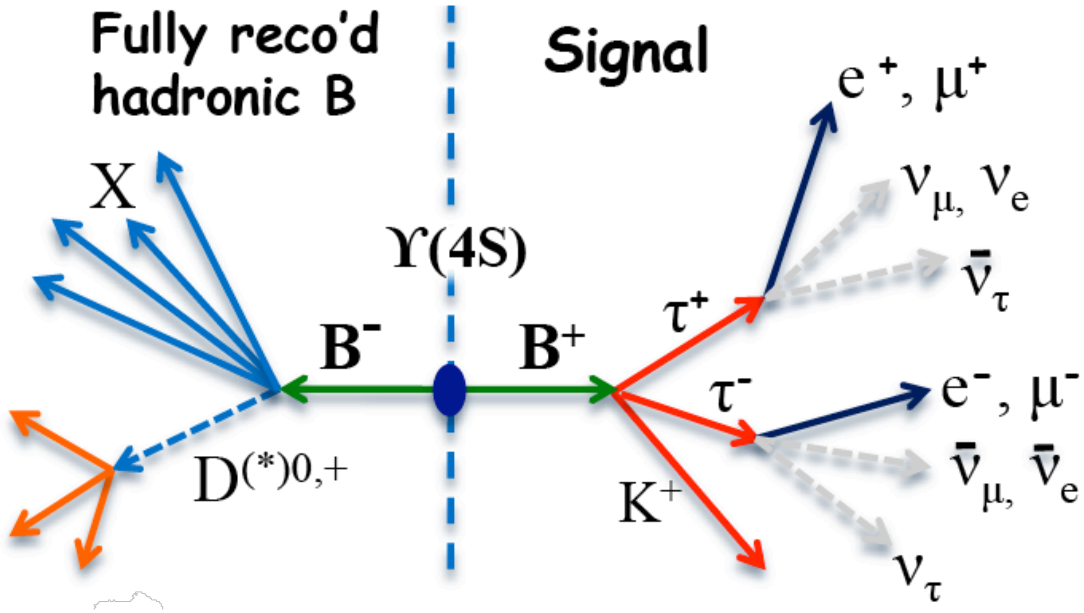
Figure 1: Feynman diagrams for $b \to s\ell^+\ell^-$ transitions.



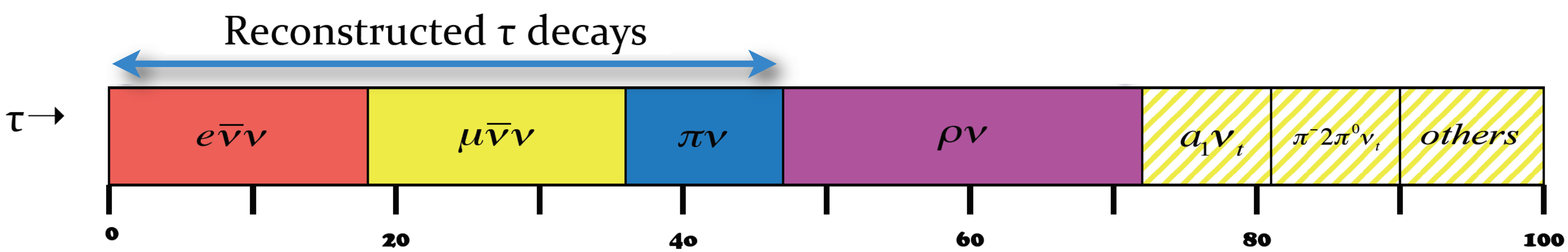
✦In the Standard Model, FCNC transitions are forbidden at tree level
✦Processes occurs via one-loop diagrams, as shown in Figure 1, albeit at a very small rate
✦Sensitive to modifications in their rates from New Physics (NP)
✦Diagrams will be altered depending on the new physics
✦The NMSSM rate enhancements is proportional to $(m_\tau/m_\mu)^2 \sim 280$

Analysis Overview

- ✦2-4 neutrinos originating from tau decay
- ✦One fully reconstructed B-meson improves background rejection and provides q^2 calculation
- ✦Remaining tracks and clusters provide "signal" variables after removing those used for the fully reconstructed B-meson
- ✦Considering 3 one-prong tau decays
- ✦Looking for a 3 charged track and no activity in the calorimeter!



$$\mathcal{B}(B^+ \to K^+\tau^+\tau^-) = \frac{N_{obs} - N_{bkg}}{\epsilon_{sig}\kappa_{tag}N_{BB}}$$



Hadronic Tag Efficiency Correction

✦Hadronic tag is seeded by $B \rightarrow D^{(*)}+X$, where X is a combination of pions and kaons

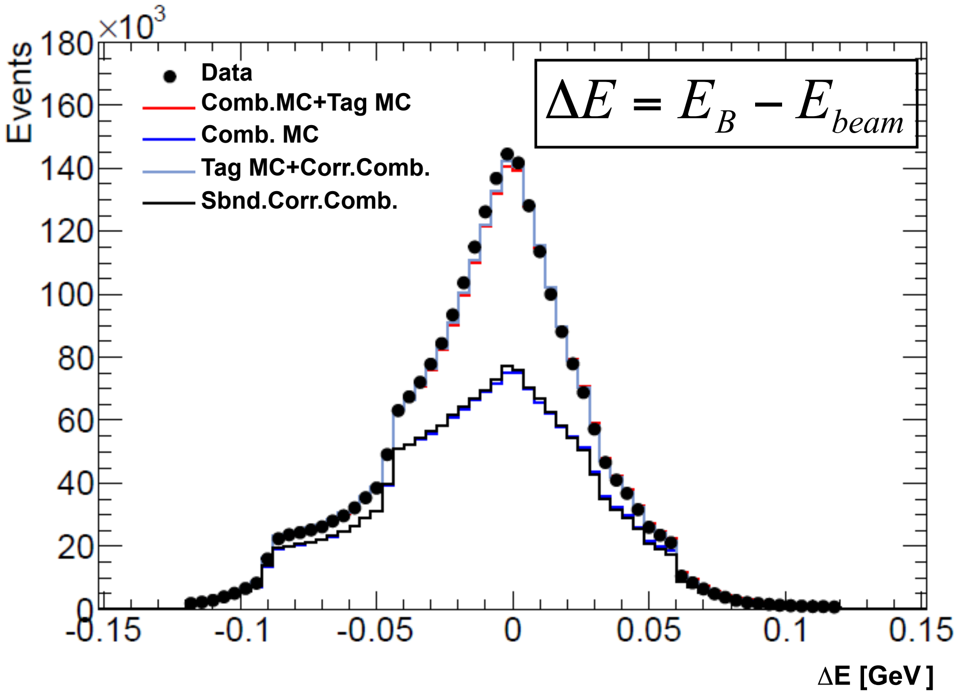
✦In the case of multiple B candidates select the one with the smallest $|\Delta E|$

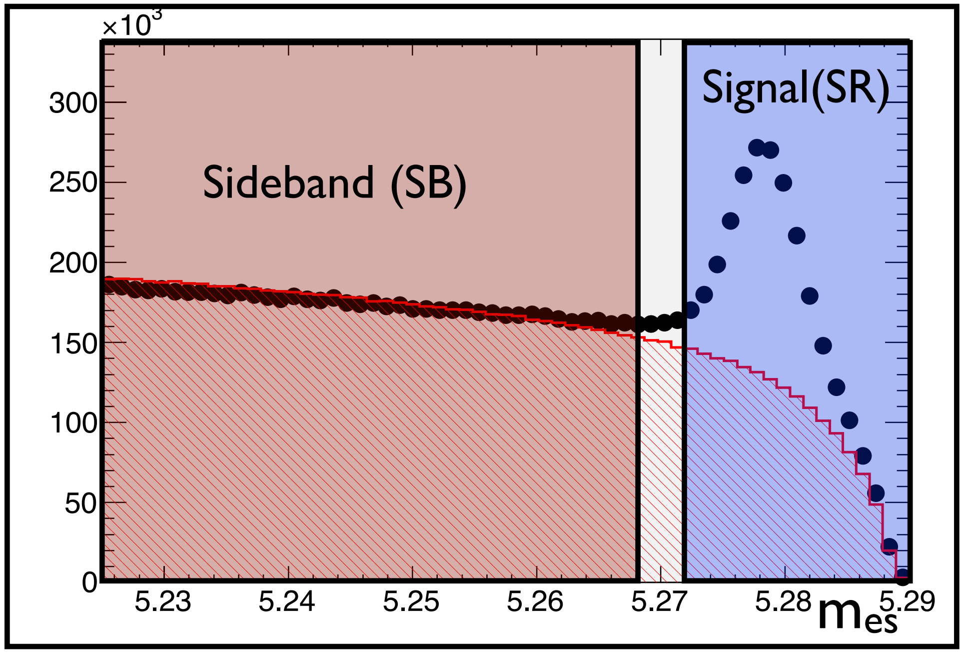
✦Estimate the continuum background using data sideband and MC ratio:

$$N_{SR}^{comb} = R^{MC} \times N_{SB}^{data} = \frac{N_{SR}^{MC}}{N_{SB}^{MC}} \times N_{SB}^{data}$$

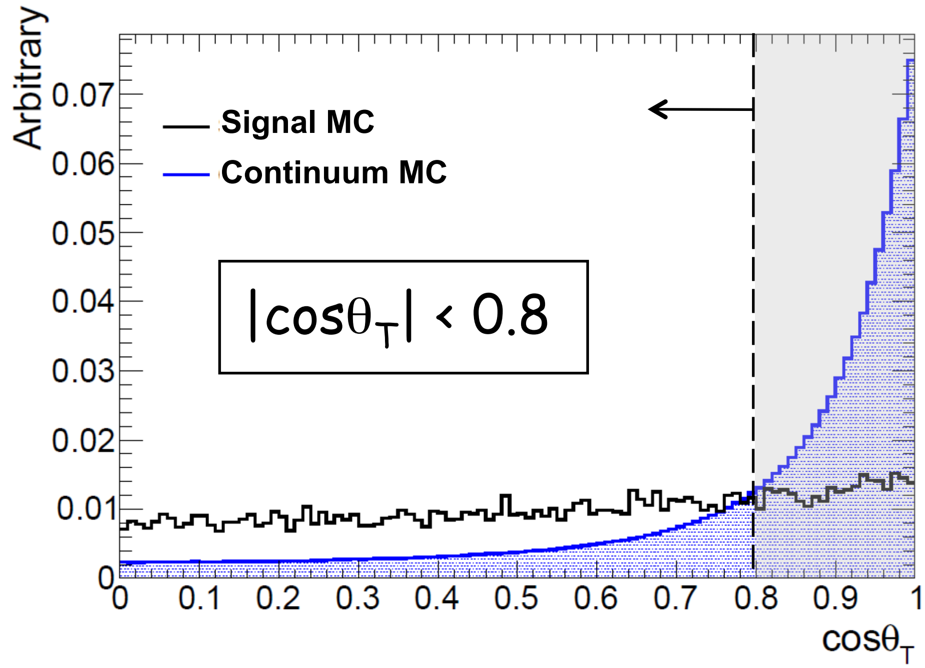
✦The "Peaking" component is estimated using B^+B^- MC

✦Efficiency Correction is κ_{tag}=0.909±0.029





Signal Selection



✦Continuum backgrounds are suppressed using $|\cos\theta_T|$, the cosine of the opening angle between the tag-B thrust and the rest-of-the-event thrust

✦Require exactly 3 tracks

✦One Charged Kaon
- Charge opposite that of the tag-B
- Momentum between 0.44-1.4 GeV/c

✦Two oppositely charged tracks
- Momentum of track with the charge opposite that of the tag-B must be < 1.59 GeV/c
- Mass of track pair < 2.89 GeV/c^2

✦Momentum Transfer: $q^2 < 14.23$ GeV^2

✦Missing Energy: $1.39 < E_{miss} < 3.38$ GeV

✦Extra neutral energy < 0.74 GeV

✦Invariant mass of the $M(K\pi) > 1.96$ GeV/c^2 to remove largest backgrounds from $B \rightarrow D + X$ decays

Systematic & Results

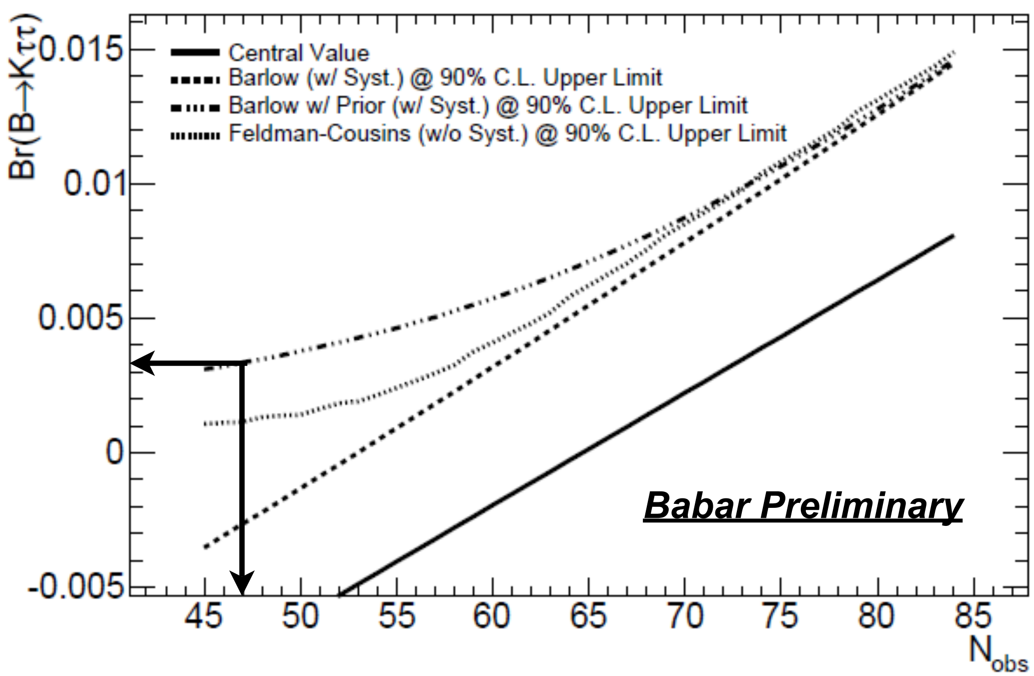
✦Several control samples (double tagged) are defined to validate/correct key discriminating variables

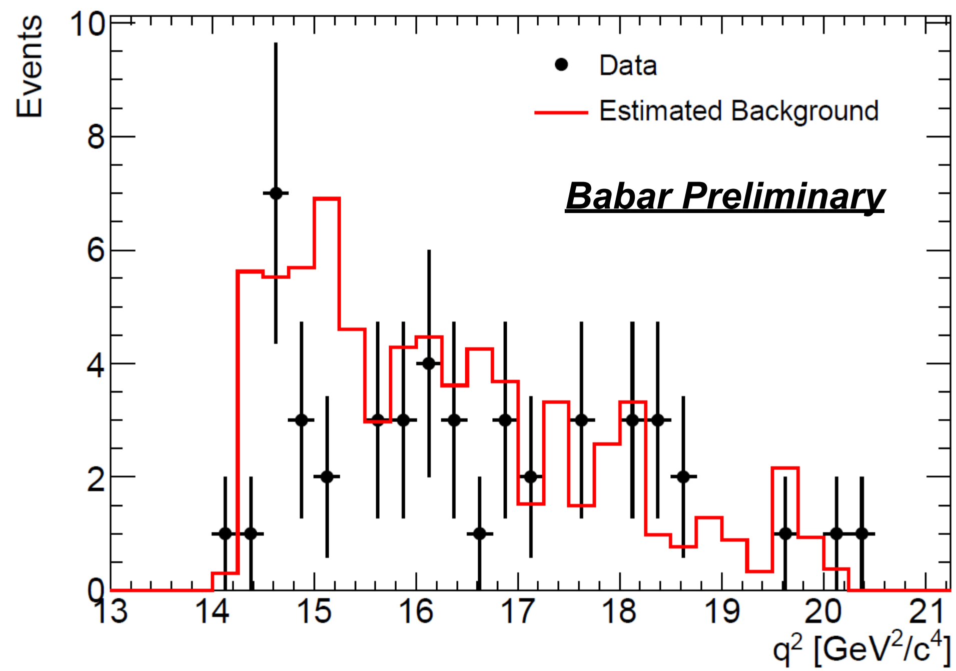
✦Expected 64.67±7.25

✦Measured 47 events

✦Br(B→Kττ)<0.33%

B-counting (δN_{BB})		1.1 %
Tag-B Efficiency Correction ($\delta\kappa_{tag}$)		3.17 %
Signal Efficiency ($\delta\epsilon_{sig}$)		14.81 %
Signal Monte-Carlo Statistics		13.87 %
Particle Identification		5.06 %
Charged Tracks		0.74 %
Extra Charge Track Veto		0.45 %
Extra Neutral Cluster Energy		0.83 %
Background Estimation (δN_{bkg})	Type	
Combinatoric Ratio from Data/MC Check	Combinatoric	10.73 %
Data m_{ES} Sideband Statistics	Combinatoric	10.21 %
Particle Identification	Peaking	5.06 %
Charged Tracks	Peaking	0.74 %
Extra Charge Track Veto	Peaking	0.45 %
Extra Neutral Cluster Energy	Peaking	0.83 %
Shape Estimation from Combinatoric Mixture	Both	7.37 %





Latest measurements for $B \to \tau\nu$ using Hadronic Tag Method

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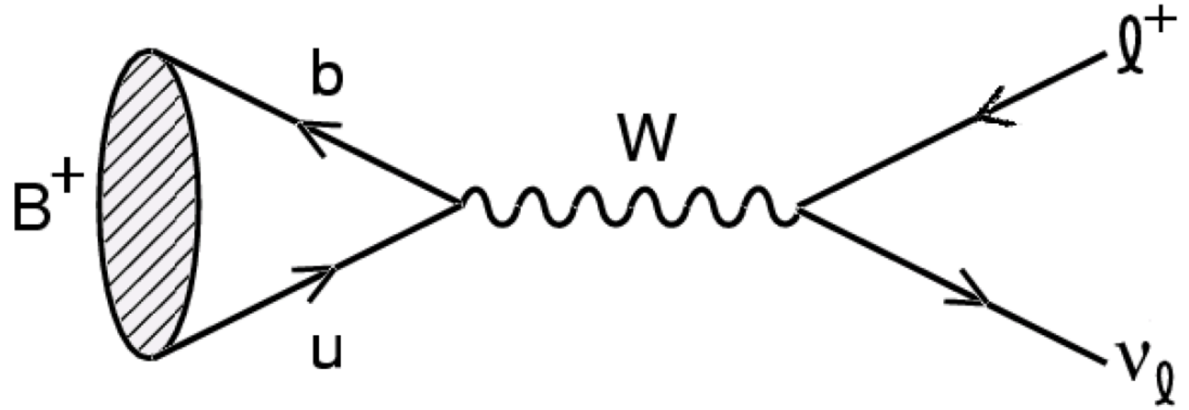
$B \rightarrow \tau\nu$ Standard Model

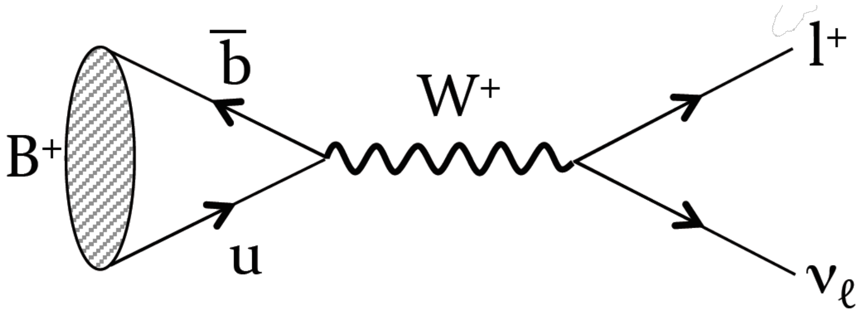


$$\mathcal{B}(B^- \to \ell^- \bar{\nu}) = \frac{G_F^2 m_B}{8\pi} m_l^2 \left(1 - \frac{m_l^2}{m_B^2}\right)^2 f_B^2 |V_{ub}|^2 \tau_B$$

✦In the Standard Model, the $B \rightarrow \tau\nu$ process is mediated by a W boson
✦Electron and muon channels are helicity suppressed
✦Can measure f_B assuming a V_{ub}
✦V_{ub} measure (exp.+theory) and f_B (theory) uncertainties dominate the SM expectation uncertainty

- $V_{ub} = (3.5 \pm 0.4) \times 10^{-3}$, UTFit and CKM fitter collaborations
- $f_B = (190 \pm 13)$ MeV, HPQCD collaboration arXiv:0902.1815v2
- $Br(B \rightarrow \tau\nu)_{SM} = (0.80 \pm 0.20) \times 10^{-4}$

B→τν New Physics Contributions



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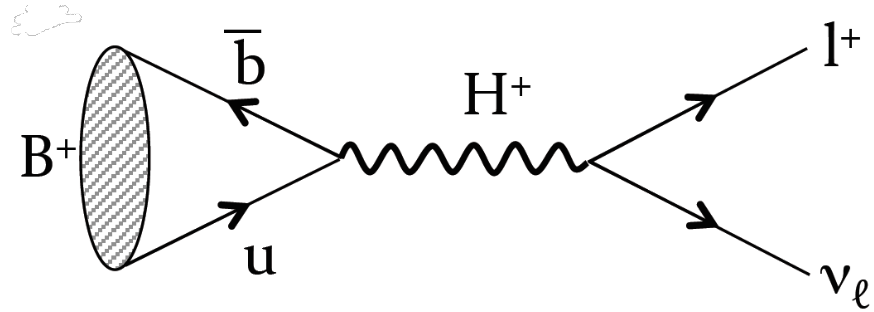


- ✦New physics, such as the Charge Higgs, can contribute at tree level
- ✦This leads to modifications in the branching fraction which is model dependent
- ✦Consequently, the Br(B→τν) measurement allows us to place exclusion limits on various NP models
- ✦Example of modification:

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

W. S. Hou, Phys. Rev. D 48 (1993) 2342.

Previous Measurements

BABAR Hadronic tags

$\mathcal{B}(B \to \tau\nu) = (1.8^{+0.9}_{-0.8}(\text{stat.}) \pm 0.4 \pm 0.2) \times 10^{-4}$ Phys. Rev. D 77, 011107(R) (2008)

BABAR Semi-leptonic tags

$\mathcal{B}(B \to \tau\nu) = (1.7 \pm 0.8 \pm 0.2) \times 10^{-4}$ Phys. Rev. D 81,051101(R) (2010)

BELLE Hadronic tags

$\mathcal{B}(B \to \tau\nu) = (1.79^{+0.56}_{-0.49}(\text{stat.})^{+0.46}_{-0.51}) \times 10^{-4}$ Phys. Rev. Lett. 97, 261802 (2006)

BELLE Semi-leptonic tags

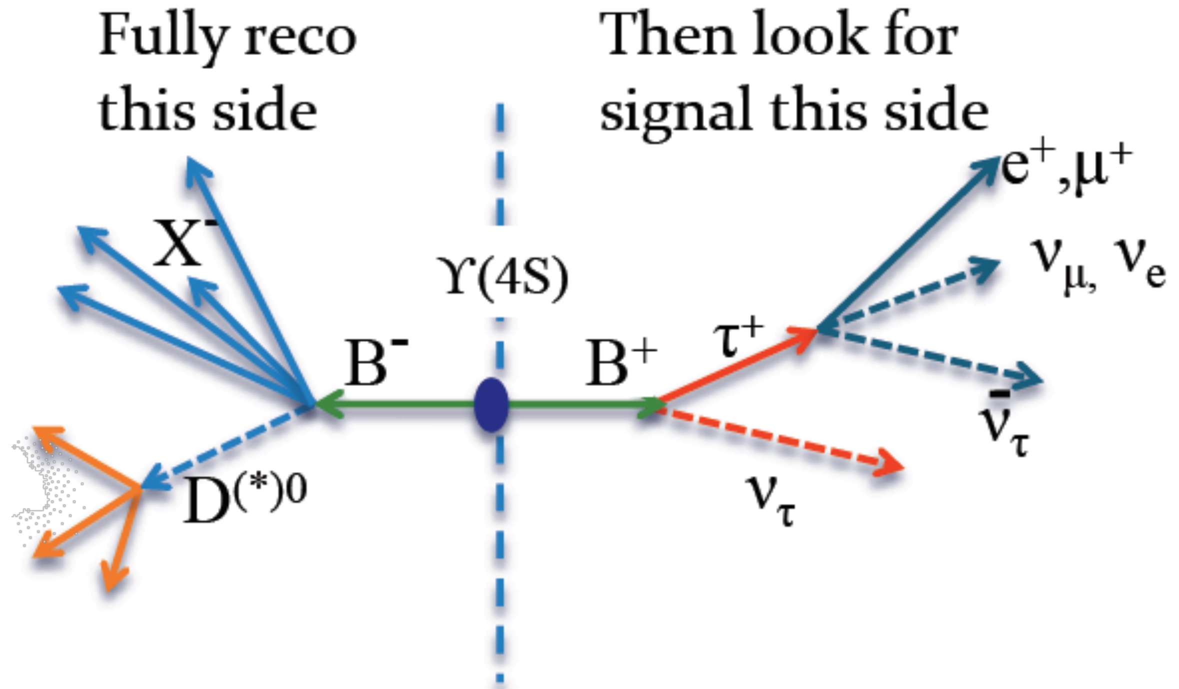
$\mathcal{B}(B \to \tau\nu) = (1.54^{+0.38}_{-0.37}(\text{stat.})^{+0.29}_{-0.31}) \times 10^{-4}$ arXiv:1006.4201[hep-ex]

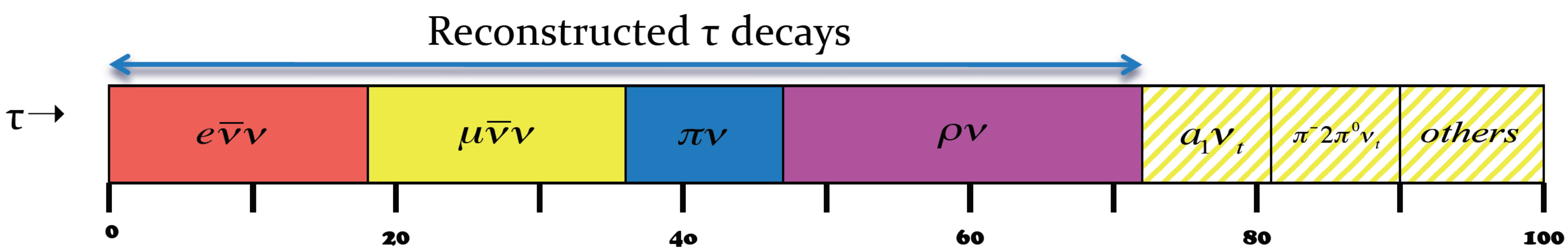
Theory

- $Br(B \to \tau\nu)_{SM} = (0.80 \pm 0.20) \times 10^{-4}$

Analysis Overview

✦2-3 neutrinos originating from leptonic W boson decay and tau decay
✦One fully reconstructed B-meson
✦Remaining tracks and clusters provide "signal" variables
✦Considering 4 one-prong tau decays
✦Looking for a single charged track and no activity in the calorimeter!





Hadronic Tag Efficiency Correction

✦Hadronic tag seed by $B \to D^{(*)}+X$ and $B \to J/\psi+X$, where X is a combination of pions and kaons

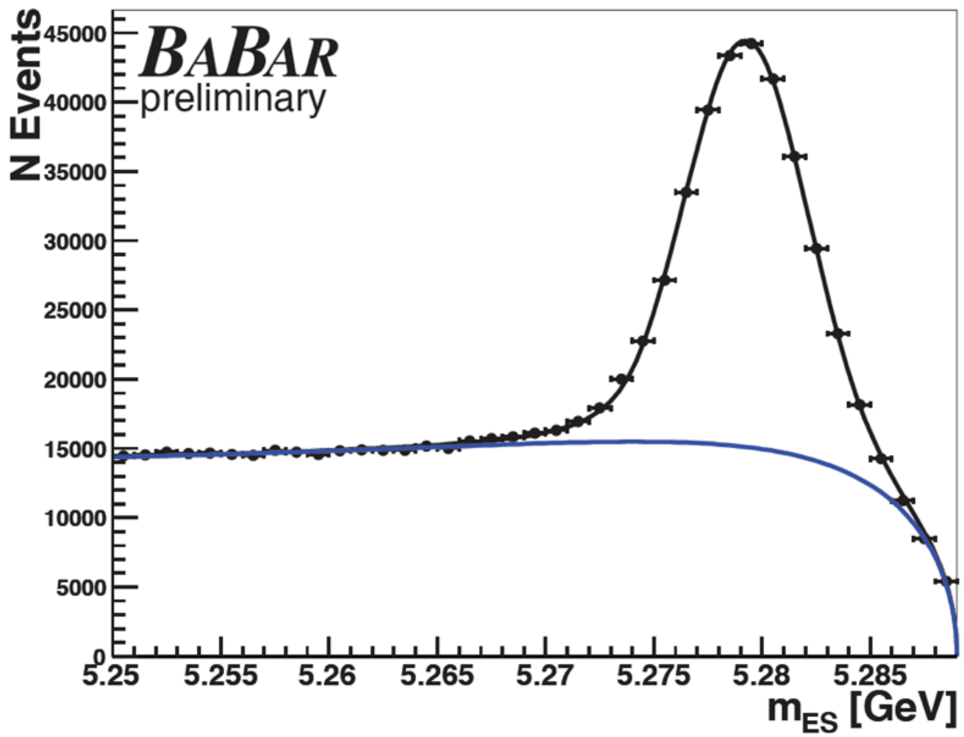
✦In case of multiple B candidates select the "best" candidate

✦Fit using a Crystal Ball+ 2 Argus

✦Crystal Ball to estimate the correctly reconstructed Bs

✦ Double Argus to estimate the combinatorial background

✦Efficiency correction is $\kappa_{tag}=R=0.926\pm0.046$



$$\epsilon_{sig,data} = R \times \epsilon_{sig,MC}$$

$$R = \frac{\epsilon_{B^+B^-,data}}{\epsilon_{B^+B^-,MC}}$$

Signal Selection

✦Combinatorial and continuum backgrounds are reduced using a likelihood ratio

✦Require on charged track with charge opposite to that of the tag-B

✦Exploit kinematics in the signal side

i. Requirement on CM momentum for $\tau^{\pm}\rightarrow e^{\pm}\nu\nu$, $\tau^{\pm}\rightarrow\mu^{\pm}\nu\nu$, and $\tau^{\pm}\rightarrow\pi^{\pm}\nu$ modes

ii. For $\tau^{\pm}\rightarrow\rho^{\pm}\nu\rightarrow\pi^{\pm}\pi^{0}\nu$, combine 4 variables in a Likelihood ratio

✦The most discriminating variable is the remaining energy in the calorimeter "Eextra"; this is defined as the sum of calorimeter energy using clusters with more than 60 MeV of energy.

Fit Strategy

✦Branching Fraction (BF) is determined using an un-binned maximum likelihood fit

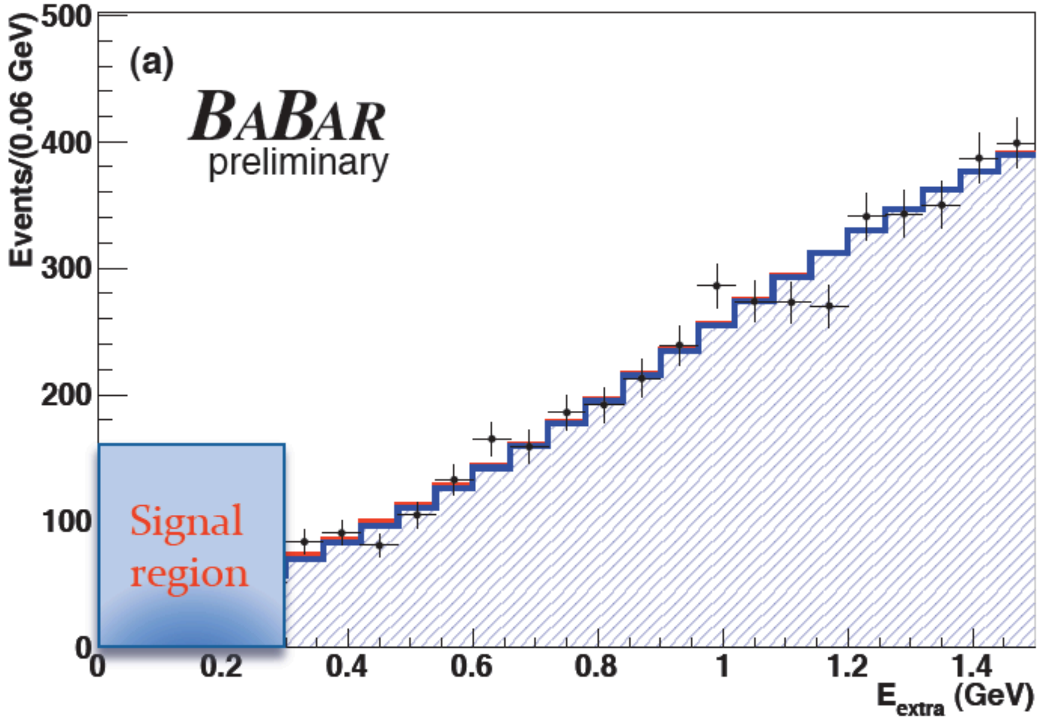
✦Simultaneously fit for a common BF

✦Signal PDFs are taken from MC and corrected for any MC/data disagreements

✦Background PDFs are taken from:

i. Data sideband for combinatoric

ii. B^+B^- MC for “peaking” component

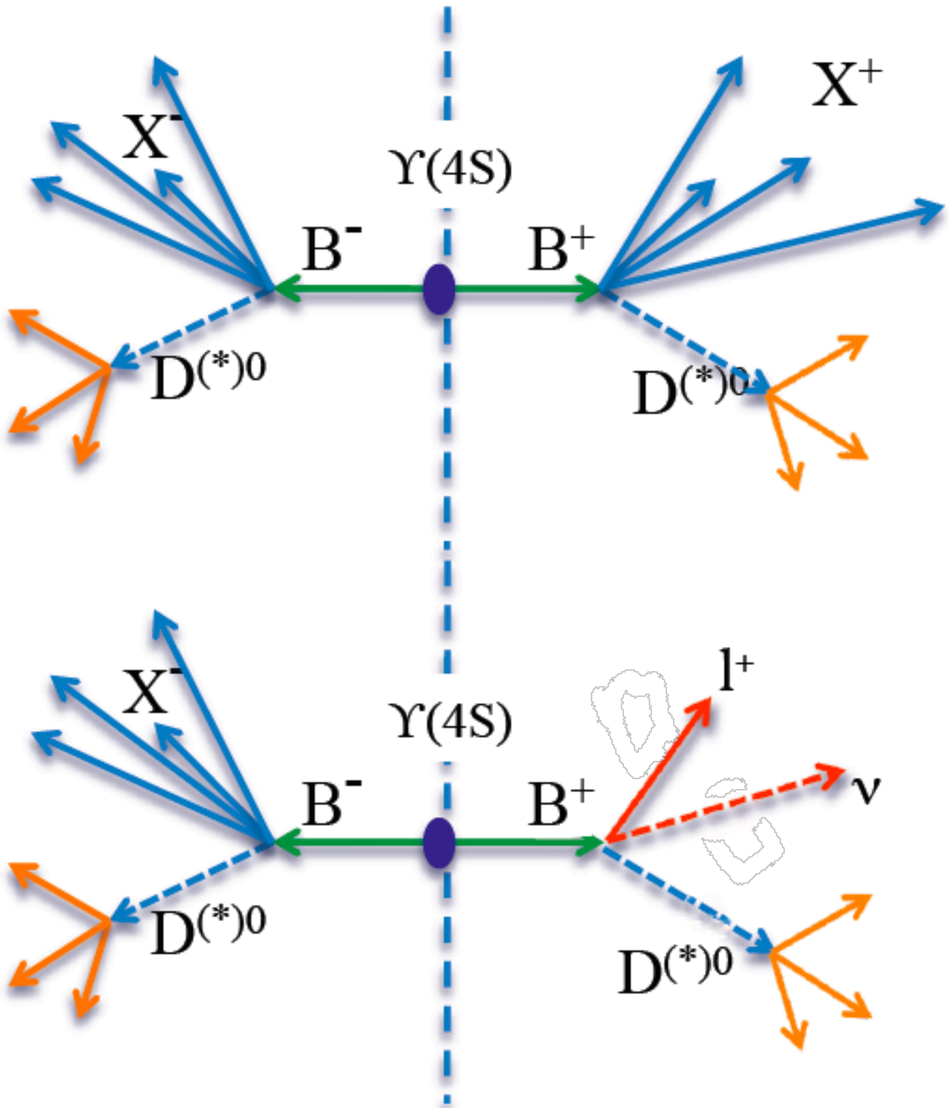


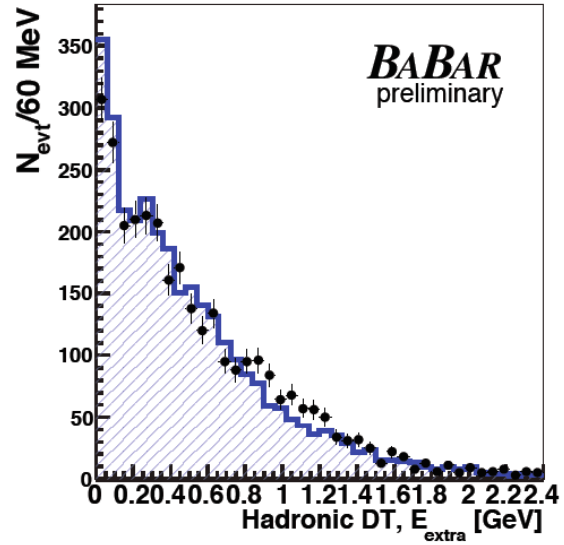
$$\mathcal{L}_k = e^{-(n_{s,k}+n_{b,k})} \prod_{i=1}^{N_k} \left\{ n_{s,k}\mathcal{P}_k^s(E_{i,k}) + n_{b,k}\mathcal{P}_k^b(E_{i,k}) \right\}$$

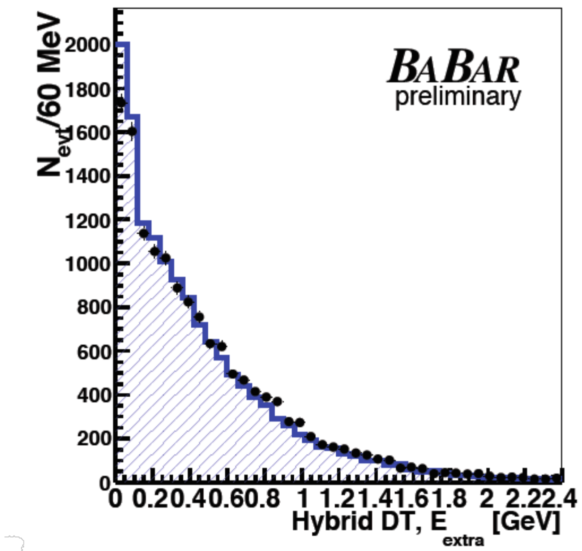
$$n_{s,k} = N_{B\overline{B}} \times \epsilon_{tag} \times \epsilon_{reco,k} \times BF$$

Validating Eextra

- ✦We use double tag samples to validate the Eextra variable

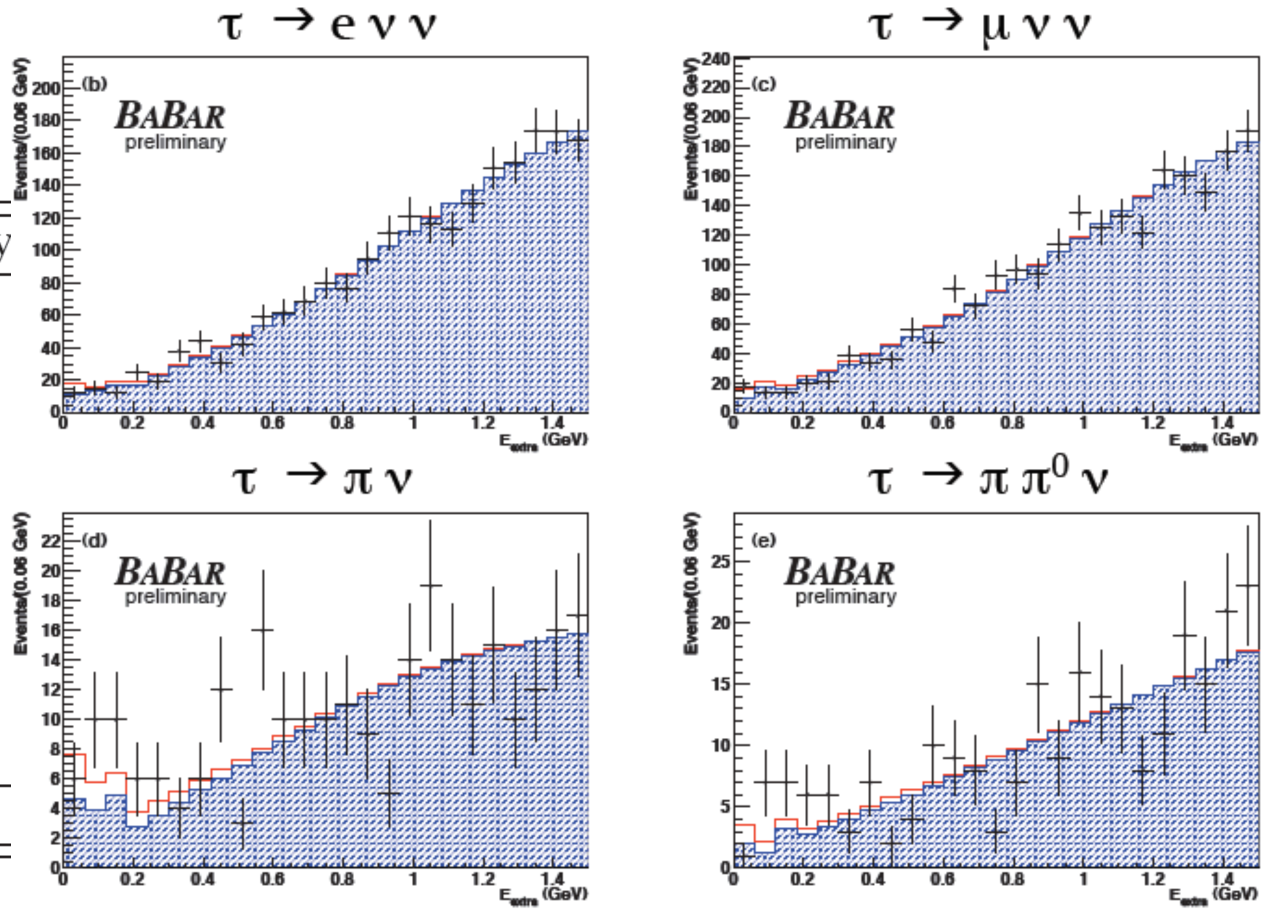






Systematics & Results

Source of systematics	BF uncertainty
B counting	0.5
Tag B efficiency	5.0
Background PDF	12
Signal PDF	1.7
MC statistics	0.8
Electron identification	2.6
Muon identification	4.7
Kaon identification	0.4
Tracking	1.4
Total	14



Decay Mode	$\epsilon \times 10^{-4}$	Branching Fraction $(\times 10^{-4})$	Significanc
$\tau^+ \to e^+ \nu \bar{\nu}$	2.97	$0.39^{+0.89}_{-0.79}$	0.5
$\tau^+ \to \mu^+ \nu \bar{\nu}$	3.20	$1.23^{+0.89}_{-0.80}$	1.6
$\tau^+ \to \pi^+ \nu$	1.71	$4.0^{+1.5}_{-1.3}$	3.3
$\tau^+ \to \rho^+ \nu$	0.93	$4.3^{+2.2}_{-1.9}$	2.6
combined	8.81	$1.80^{+0.57}_{-0.54}$	3.6

$$\mathcal{B}(B^+ \to \tau^+ \nu_\tau) = (1.80^{+0.57}_{-0.54} \pm 0.26) \times 10^{-4}$$

Conclusion

✦New preliminary measurement on the search for the B→Kττ process to the full BABAR dataset using an hadronic B tagging algorithm

✦The upper limit at 90% C.L. is:

$$\mathcal{B}(B^+ \to K^+\tau^+\tau^-) < 0.33\%$$

✦Updated the B→τν branching fraction measurement to the full BABAR dataset using an hadronic B tagging algorithm

✦New branching fraction is:

$$\mathcal{B}(B^+ \to \tau^+\nu_\tau) = (1.80^{+0.57}_{-0.54} \pm 0.26) \times 10^{-4}$$

✦The combined Babar results is

$$\mathcal{B}(B^+ \to \tau^+\nu_\tau) = (1.76 \pm 0.49) \times 10^{-4}$$