Experimental Prospects for $B \to X_s \tau^+\tau^-$, $B^0 \to l^+\tau^-$ and related modes

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SuperB

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Outline

- Hadronic tag reconstruction method
- Leptonic B decays: $B^+ \rightarrow l^+ \nu$ (l=e,μ)
- $B^+ \rightarrow l^+ \nu \gamma$
- LFV modes: $B^0 \rightarrow \tau^{-/+} \mu^{+/-}$ and $B^+ \rightarrow K^+ \tau^{-/+} \mu^{+/-}$
- $B \rightarrow K^{(*)} \tau^{-/+} \tau^{+/-}$

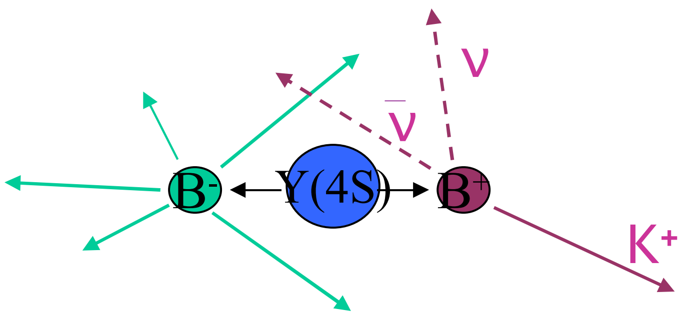
Hadronic tag reconstruction

Use tag reconstruction (aka "recoil method") for decays which otherwise lack sufficient constraints to identify the signal

- BABAR uses a method based on a $D^{(*)}$ seed, to which individual charged and neutral pions and kaons are added until a B candidate is identified

Advantages:

- clean separation of signal and tag decay products
- strong suppression of (and precise determination of) continuum backgrounds
- knowledge of tag (and hence signal B) 4-vector
- improved determination of missing energy



$B^- \rightarrow D^{(*)0} X^-$

- → $K^- \pi^+$
- → $K^- \pi^+ \pi^0$
- → $K^- \pi^+ \pi^- \pi^+$
- → $K^0_s \pi^+ \pi^-$

Disadvantage:

- efficiency

$B^{+/-}$ tag reconstruction

Realistic tagging efficiency (per $B^{+/-}$) of ~0.24% in events containing a low-multiplicity "signal" event

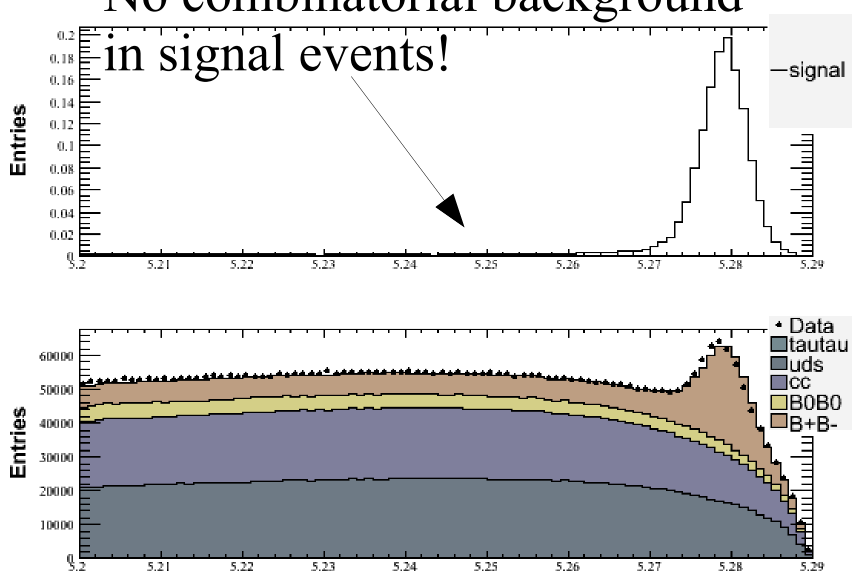
- typically "signal-side" selection is fairly efficient (~10% - 70%)

Assuming 30% gives "single-event sensitivity" at

$Br(B \rightarrow rare) \sim 3\times10^{-6}$ with 500 fb^{-1}

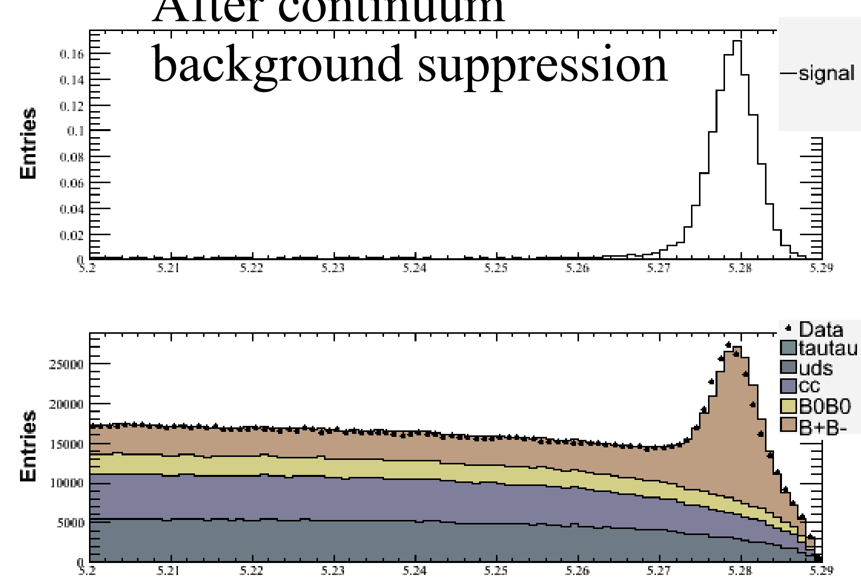
$Br(B \rightarrow rare) \sim 3\times10^{-8}$ with 50 ab^{-1}

No combinatorial background in signal events!



m_{ES} (GeV/c^2)

After continuum background suppression



m_{ES} (GeV/c^2)

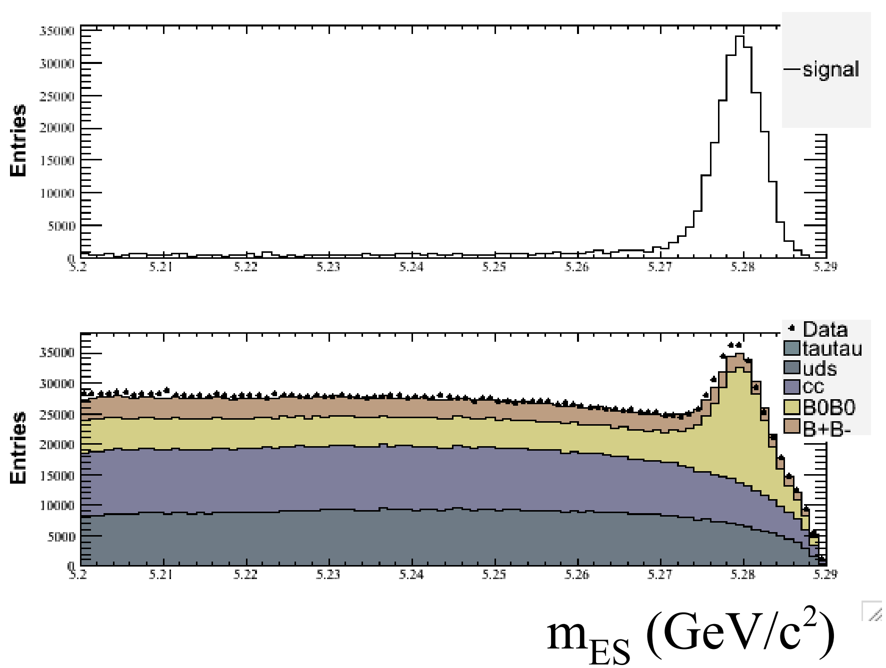
Neutral B tags

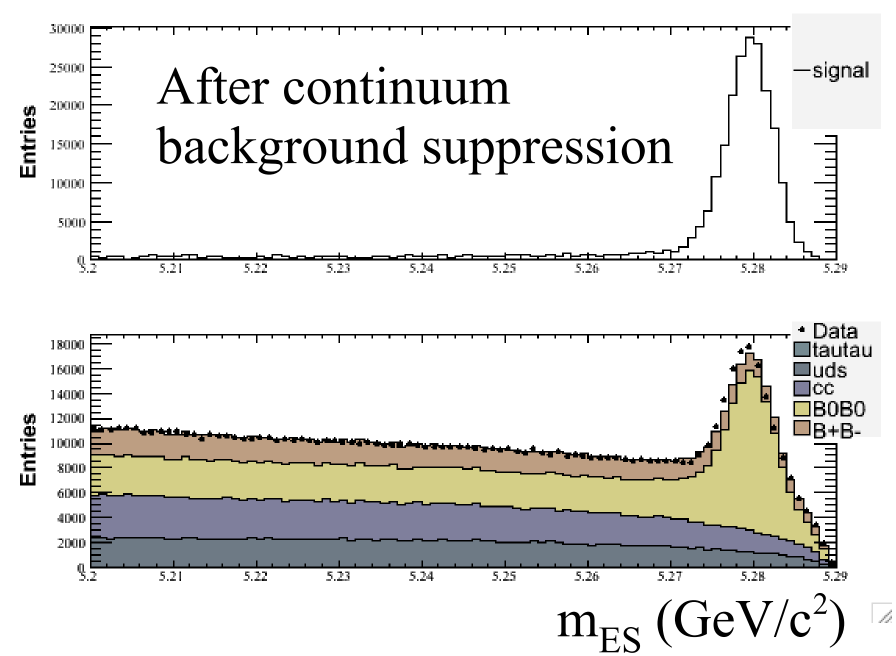
Realistic tagging efficiency (per B^0) of ~0.16% in events containing a low-multiplicity "signal" event

Assuming 30% gives "single-event sensitivity" at

$$Br(B \rightarrow \text{rare}) \sim 4.5\times10^{-6} \quad \text{with } 500\ fb^{-1}$$

$$Br(B \rightarrow \text{rare}) \sim \sim 4.5\times10^{-8} \quad \text{with } 50\ ab^{-1}$$

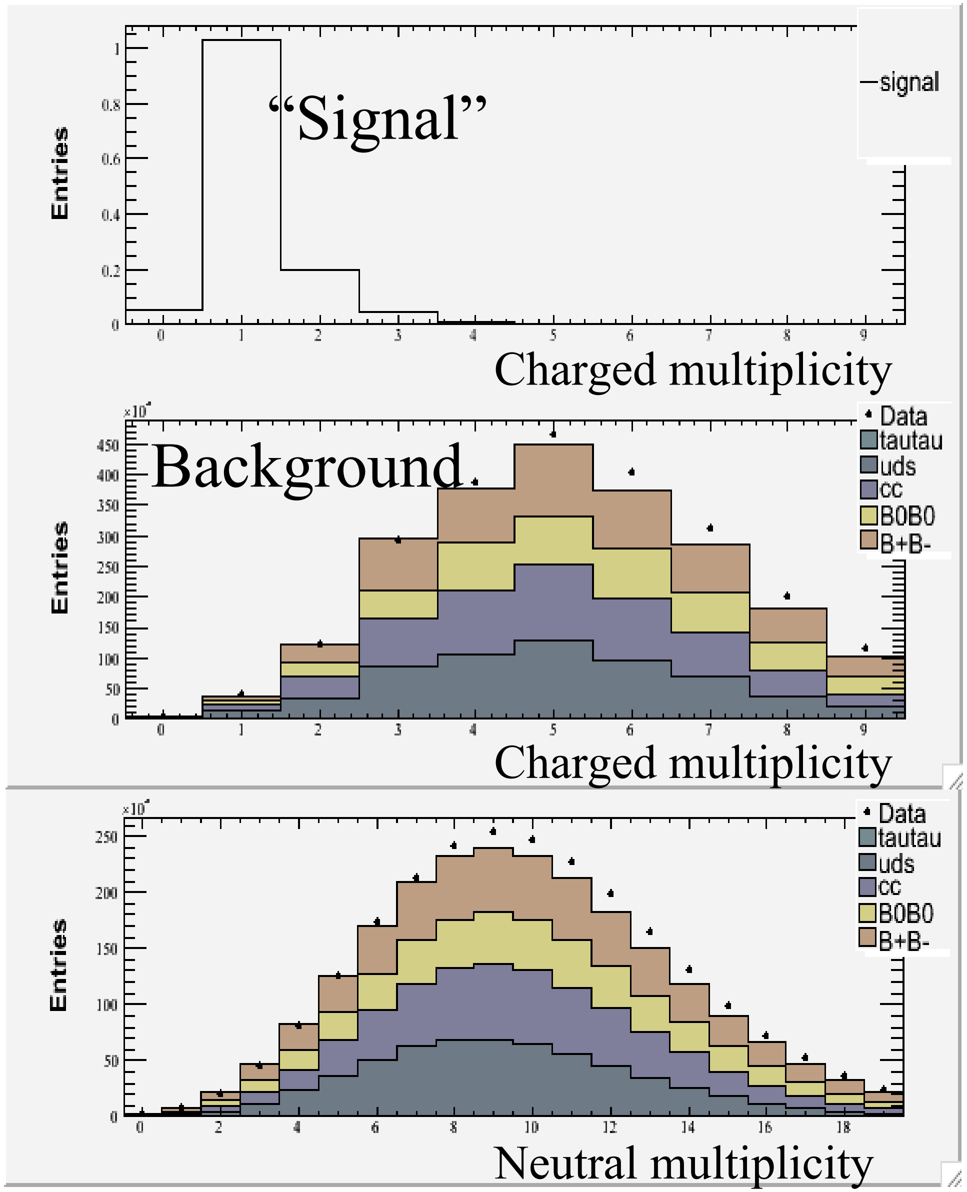




Caveats

Searches for modes with missing energy rely heavily on the low multiplicity of the signal to keep backgrounds managable

- higher multiplicity requires harder cuts or additional kinematic handles
- Detector non-hermiticity and/or non-physics “junk” is a killer
- Tag reconstruction is usually CLEANER in these events, so can potentially use tag modes that appear to be too messy in “generic” B decays



Caveats

Tag B reconstruction efficiency scales non-linearly with tracking and calorimeter acceptance

- Not clear what the impact of reduced beam energy asymmetry will be

Need to balance reconstruction efficiency against cleanliness of the reconstruction by careful choice of what modes to reconstruct

- Potential for significant efficiency gain by including e.g. $D^0 \to K^+\pi^-2\pi^0$, or purity gain by including e.g. J/Ψ - seeded decays

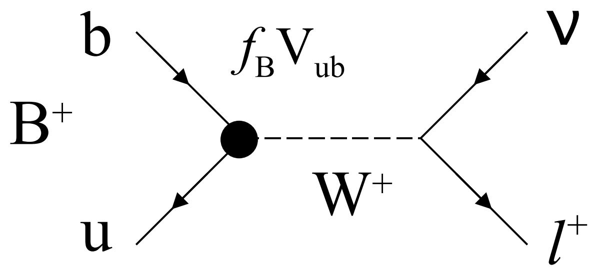
Devil is in the details!

- performance of vertexing, kinematic fitting, track-cluster matching, presence of tracking and/or calorimeter artifacts etc etc.

⇒ **Important to study impact of proposed detector design**

Leptonic B decays

Leptonic B decays are helicity-suppressed EW tree processes in the SM:



Standard Model Rates

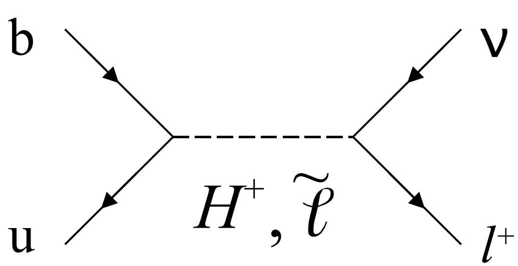
$B(B^+ \rightarrow \tau^+\nu) \sim 1\text{x}10^{-4}$

$B(B^+ \rightarrow \mu^+\nu) \sim 4\text{x}10^{-7}$

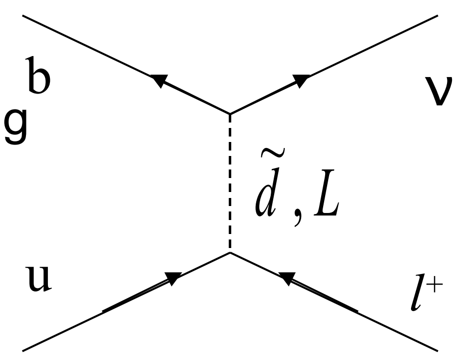
$B(B^+ \rightarrow e^+\nu) \sim 10^{-12}$

$$\mathcal{B}r(B^+ \to \ell^+ \nu_\ell) = \frac{G_F^2}{8\pi} |V_{ub}|^2 f_B^2 m_B m_\ell^2 \tau_B \left(1 - \frac{m_\ell^2}{m_B^2}\right)^2$$

New physics contributions can arise from diagrams with internal lines containing non-SM particles:



Charged Higgs, R-parity violating SUSY scalar sparticles, Pati-Salam leptoquarks...



NP @ tree level and beyond

Tree-level charged Higgs (Type-II 2HDM or MSSM) contribution has the same effect on all leptonic modes:

$$\mathrm{B}(B^+\to l^+\nu)^{\mathrm{MSSM}} = \mathrm{B}(B^+\to l^+\nu)^{\mathrm{SM}} \times \left[\, 1 - (m^2_B/m^2_{H+})\tan^2\beta/(1+\epsilon_0\tan^2\beta) \,\right]^2$$

- "Universality" preserved at tree level

At one-loop level, potentially large **Lepton Flavour Violation (LFV)** effects entering from e.g. SUSY in grand unification scenarios:

i.e. $\mathbf{B^+ \to l'^+ \nu_{l'}}$ where $l' \neq l$ via effective $l\,H^+\nu$ coupling

Observable effects in ratios, $R_b^{l/\tau}$, of B leptonic branching ratios:

$$\left(R_B^{\ell/\tau}\right)^{\mathrm{MSSM}}_{\mathrm{LFV}} = \left(R_B^{\ell/\tau}\right)^{\mathrm{SM}}\left[1 + \frac{1}{R_{B\tau\nu}}\left(\frac{m_B^4}{M_{H\pm}^4}\right)\left(\frac{m_\tau^2}{m_\ell^2}\right)|\Delta_R^{\tau\ell}|^2\frac{\tan^6\beta}{(1+\epsilon_0\tan\beta)^2}\right]$$

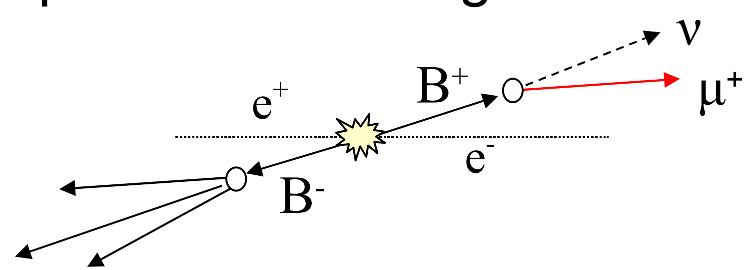
- Uncertainties from V_{ub} and f_B cancel in ratio of modes!

⇒ **NEED DETERMINATION OF BOTH τ AND μ MODES**

G. Isidori and P. Paradisi hep-ph/0605012
A. Masiero, P. Paradisi and R. Petronzio hep-ph/0511289

Inclusive $B^+ \rightarrow l^+\nu$ (l = e, μ)

Reconstruct accompanying B by 4-vector sum of particles recoiling against a high momentum lepton



- Recent Belle analysis based on 253 fb^{-1}:
- Efficiencies much higher than tagged method:

$\epsilon_\mu=(2.18 \pm 0.06)\%$ $\epsilon_e=(2.39 \pm 0.06)\%$

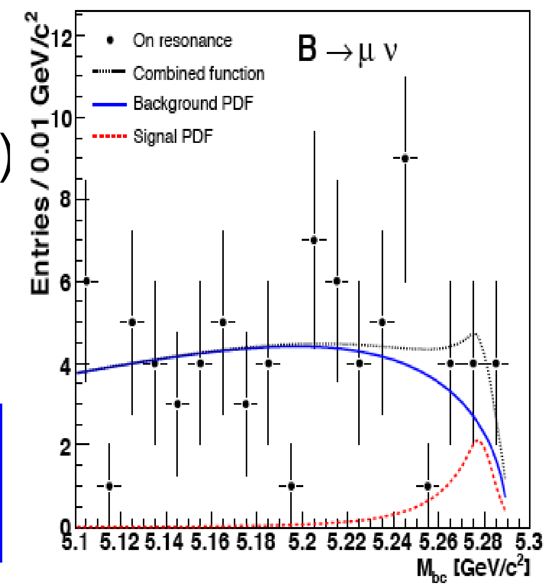
...but also higher backgrounds (~10 events in each mode)

- Extract signal from fit to M_{bc} distribution in region:

5.1<M_{bc}< 5.29; -0.8 (-1.0) <ΔE<0.4 GeV for μ(e)

$B(B^+ \rightarrow \mu^+\nu) < 1.7 \times 10^{-6}$
$B(B^+ \rightarrow e^+\nu) < 0.98 \times 10^{-6}$

hep-ex/0611045



Experimental sensitivity within a factor of ~2 of SM rate for $\mathbf{B^+ \rightarrow \mu^+\nu}$!

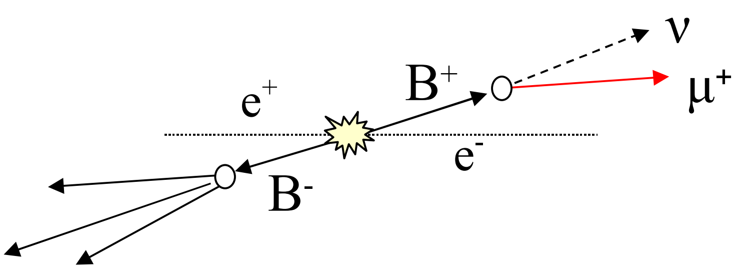
- Similar method has been used in previous publications by BABAR, Belle and Cleo

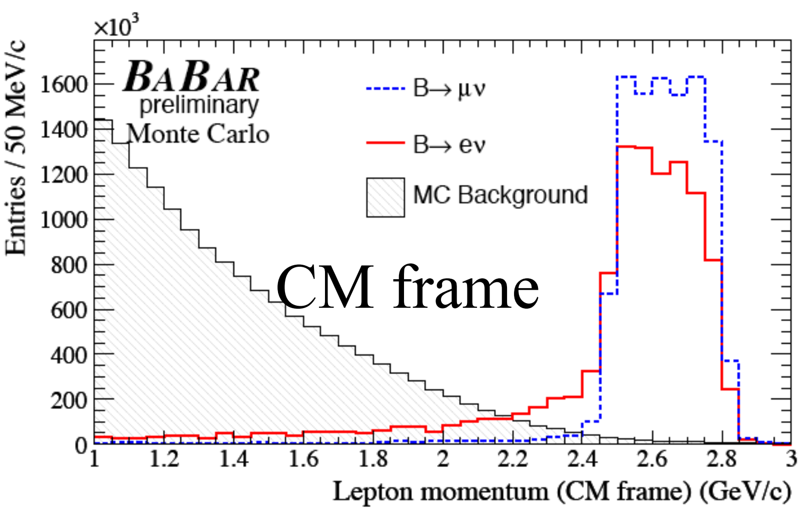
Tagged $B^+ \to l^+\nu$ ($l = e, \mu$)

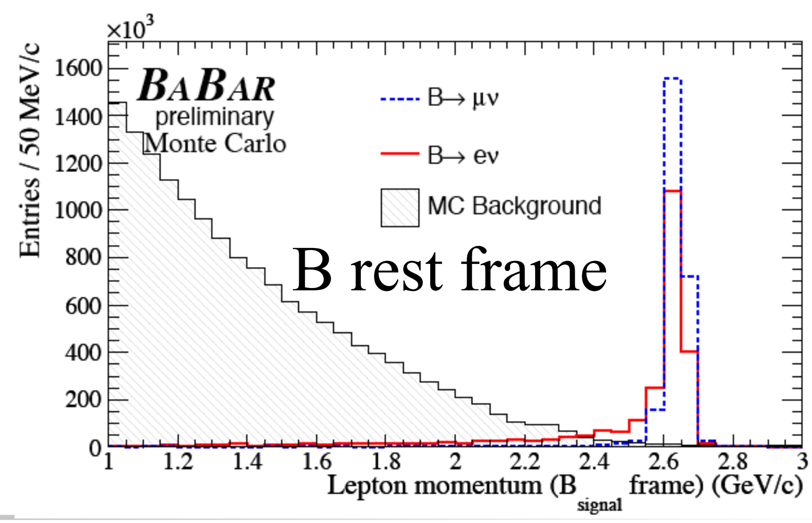
arXiv:0801.0697[hep-ex]
(Submitted to PRD RC)

Can use the hadronic B reconstruction method to search for other leptonic modes (e, μ) as well as τ mode

- only 1 neutrino, so reconstruction of tag B completely constrains event kinematics
- Signal B rest frame estimated from tag B 4-vector, permitting 2-body signal kinematics to be exploited

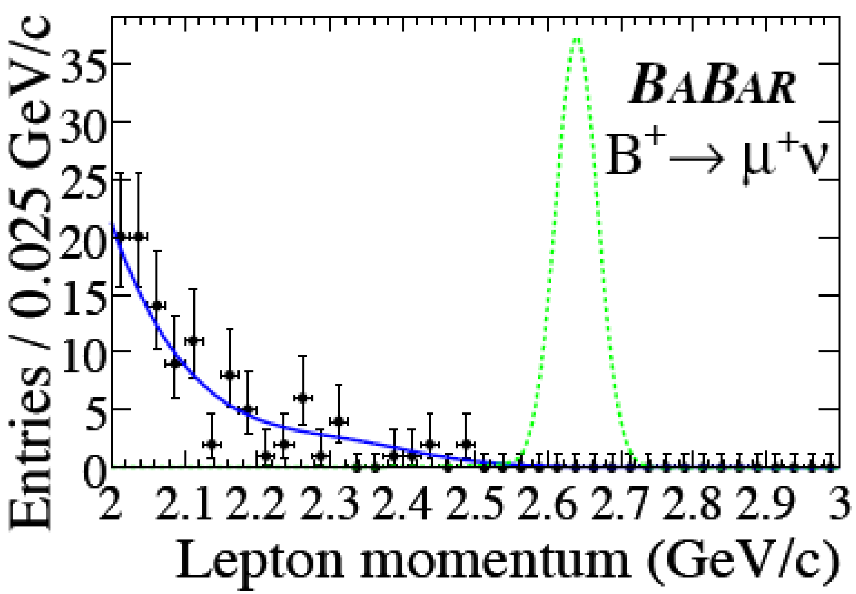






Tagged $B^+ \to l^+\nu$ (l = e, μ)

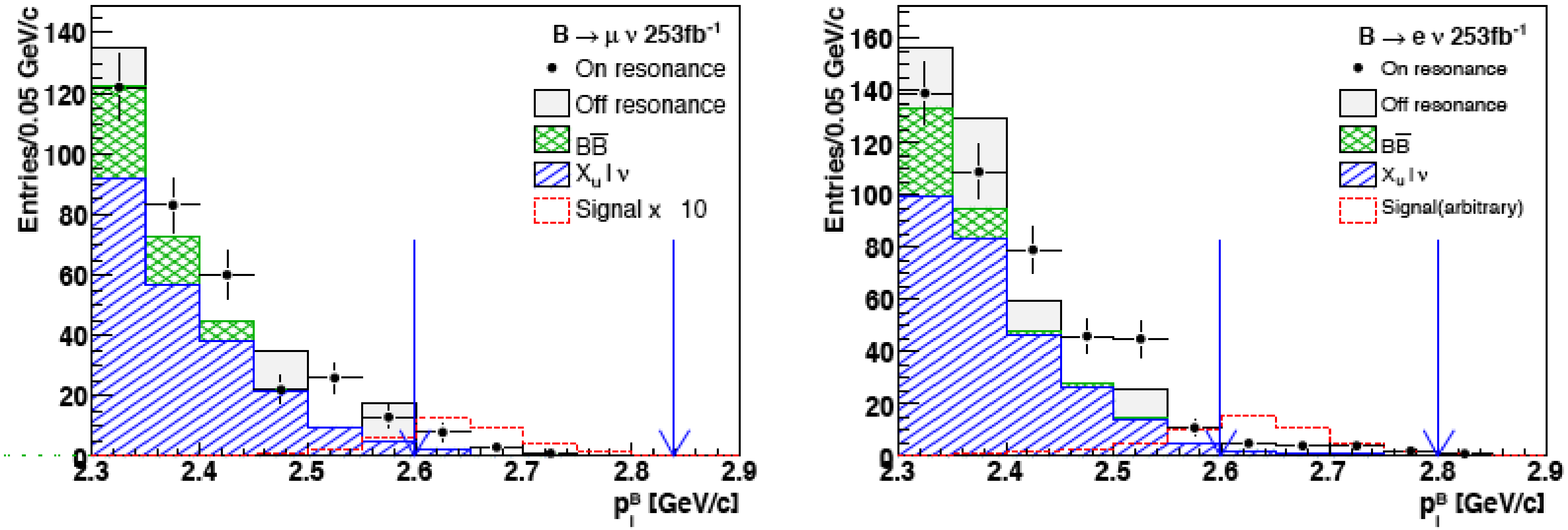
- Signal lies at kinematic endpoint in lepton p* for B decays, hence essentially no B background
- Continuum background can produce high p* leptons, but this background can be directly determined from data using the tag B m_{ES} sideband
- Narrow signal peak would lead to a very compelling signal with a very small number of events



	$e^+\nu$	$\mu^+\nu$
$\epsilon_{tot} \times 10^5$	135 ± 4	120 ± 4
n_b^* MC	2.66 ± 0.13	5.74 ± 0.25
n_b^*	2.67 ± 0.19	5.67 ± 0.34
n_s^*	-0.07 ± 0.03	-0.11 ± 0.05
$\mathcal{B} \times 10^{-6}$	$-0.1^{+2.6}_{-1.7}$	$-0.2^{+2.7}_{-1.8}$
$\mathcal{B}^{90\%\ C.L.}$	5.2×10^{-6}	5.6×10^{-6}

Inclusive $B^+ \to l^+\nu$ ($l = e, \mu$)

In inclusive analysis, signal B rest frame is not as well determined, hence p* distribution of both signal and background is smeared out:



	Muon Mode	Electron Mode
Signal Efficiency (fit region)	$3.15 \pm 0.07\,\%$	$3.86 \pm 0.08\,\%$
Signal Efficiency (signal region)	$2.18 \pm 0.06\,\%$	$2.39 \pm 0.06\,\%$
Observed in Signal region [events]	12	15
Expected background [events]	7.4 ± 1.0	13.4 ± 1.4
Signal yield [events]	4.1 ± 3.1	-1.8 ± 3.3
Significance	1.3	–
SM Prediction [events]	2.8 ± 0.2	$(7.3 \pm 1.4) \times 10^{-5}$

Tagged vs Inclusive

- BABAR : 342 fb^{-1} arXiv:0801.0697[hep-ex] (Submitted to PRD RC)

  $B(B^+ \to \mu^+ \nu) < 5.6 \times 10^{-6}$ $B(B^+ \to e^+ \nu) < 5.2 \times 10^{-6}$

- Belle: 253 fb^{-1} Phys.Lett.B647:67-73,2007. (hep-ex/0611045)

  $B(B^+ \to \mu^+ \nu) < 1.7 \times 10^{-6}$ $B(B^+ \to e^+ \nu) < 0.98 \times 10^{-6}$

So why is this interesting? Inclusive method is clearly better, right?

$\Rightarrow$ Suppose $B(B^+ \to \mu^+ \nu) = 2\times10^{-6}$ in nature and assume we have 342 fb^{-1} of data

- **Tagged:** mean of 1 signal event with an expected background <<1

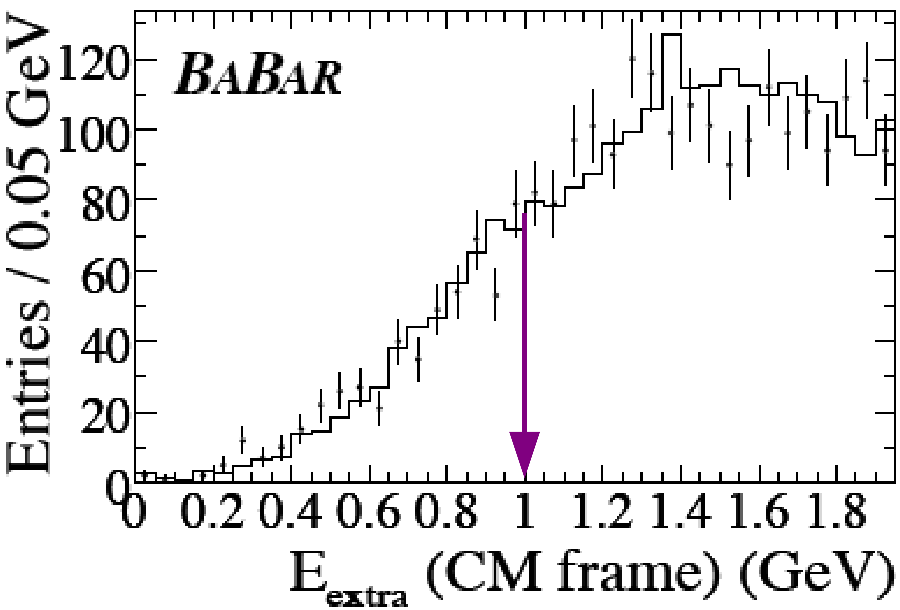
  ~50% probability of 5σ or greater signal significance

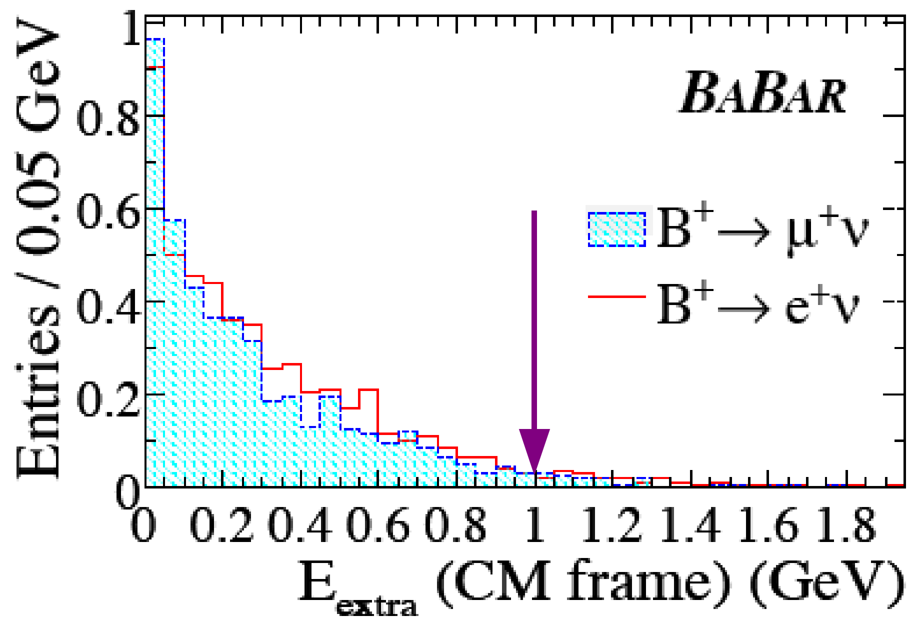
- **Inclusive:** mean of ~16 signal events with an expected background of ~12 events

  ~50% probability of 5σ or greater signal significance

Present tag analysis cuts extremely loosely on all signal-side quanities in order to maintain highest possible efficiency

- e.g. E_{extra} <1.0 GeV
- Can reduce background by factor of 2 or more with very modest reduction of signal efficiency:





⇒ Tagged analysis likely to scale somewhat better than 1/sqrt(Lumi)

$B^+ \to l^+\nu\gamma$ (l = e, μ)

Presence of hard photon removes helicity suppression of leptonic B decays restoring lepton universality

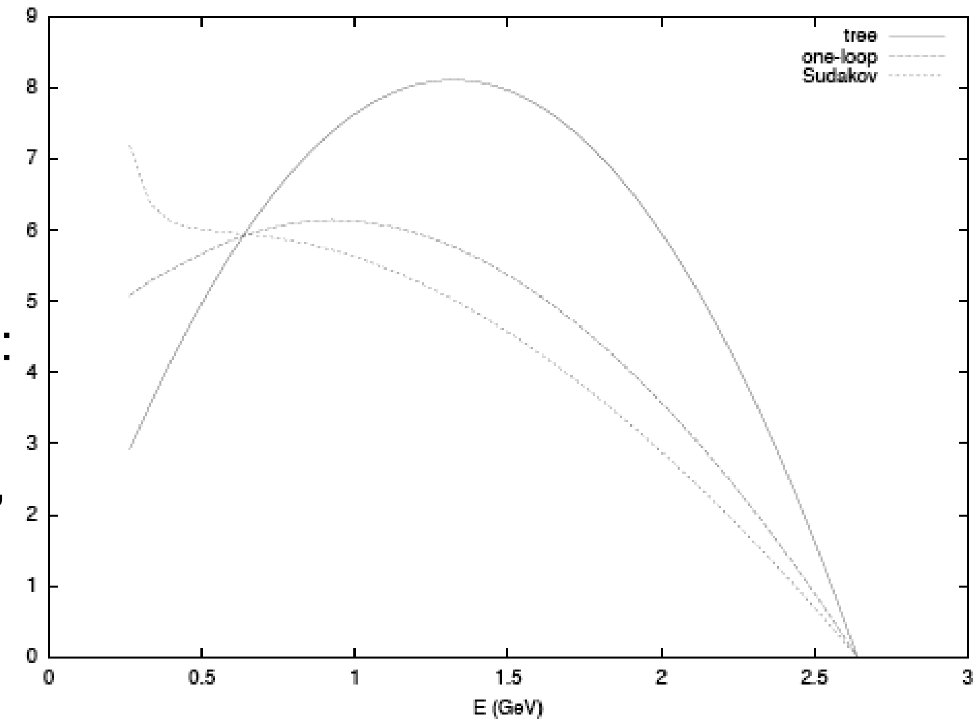
$$\Gamma(B^+ \to l^+\nu\gamma) = \alpha \frac{G_F^2 |V_{ub}|^2 m_B^5}{288\pi^2} f_B^2 \left(\frac{Q_u}{\lambda_B} - \frac{Q_b}{m_b}\right)^2$$

where λ_B is related to B light cone distribution amplitude

$Br(B^+ \to l^+\nu\gamma) \sim (1\text{-}5)\times 10^{-6}$

- nicely within sensitivity range of tagged analysis
- photon spectrum is quite hard:

  G. Korchemsky, D. Pirjol, T.-M. Yan Phys. Rev. D61:114510, 2000. (hep-ph/9911427)



Inclusive $B^+ \to l^+ \nu\gamma$ results

Previous searches have all used inclusive (non-tagged) method, most recently a BABAR analysis based on 210.5 fb^{-1}:

arXiv:0704.1478 [hep-ex] (Submitted to Phys.Rev.Lett.)

- determines ΔB in a restricted region of phase space from a simultaneous fit to the yields in the signal region and several sideband regions

- No evidence for signal and very stringent limits obtained:

	Prior flat in amplitude	Prior flat in BF
Muon	$< 1.5 \times 10^{-6}$	$< 2.1 \times 10^{-6}$
Electron	$< 2.2 \times 10^{-6}$	$< 2.8 \times 10^{-6}$
Joint	$< 1.7 \times 10^{-6}$	$< 2.3 \times 10^{-6}$

Muon channel				
	S	B1	B2	B3
Fit cont.	20.0±11.8	116.3±14.7	42.6±12.8	213.2±42.1
Off-peak	23.0±16.2	158.1±40.8	17.4±12.3	219.7±45.8
Fit $B\overline{B}$	59.1± 8.5	61.0± 9.9	61.7± 9.8	286.6±46.6
Fit signal	−5.2±13.8	−1.3± 3.4	−0.4± 1.0	−0.2± 0.5
Total fit	74.0± 8.1	176.0±12.4	103.9± 9.8	500.0±22.1
On-peak	73.0± 8.5	170.0±13.0	111.0±10.5	498.0±22.3

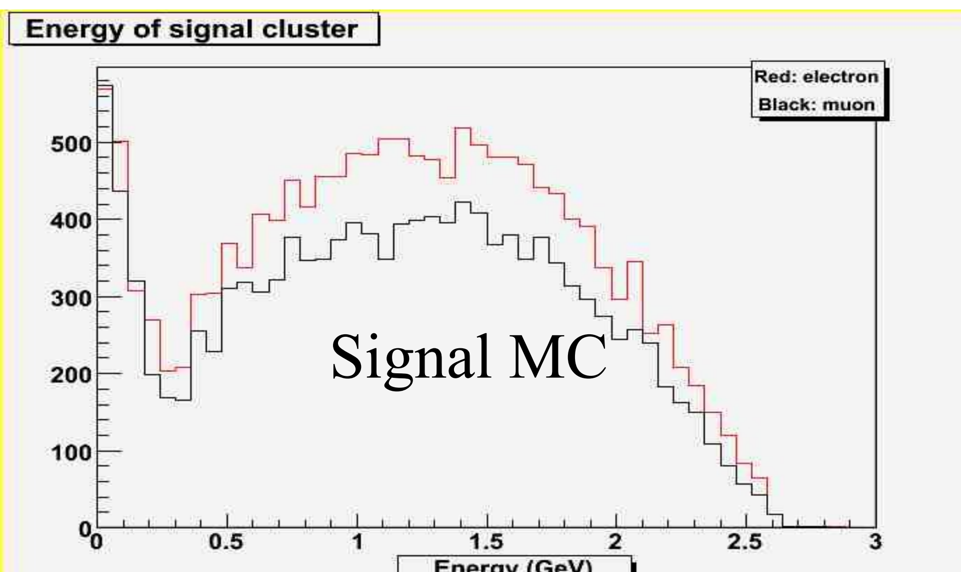
Electron channel				
	S	B1	B2	B3
Fit cont.	55.4±20.5	181.1±16.2	48.9±14.1	356.7±54.4
Off-peak	41.4±20.7	239.7±48.9	79.0±27.9	294.5±52.9
Fit $B\overline{B}$	69.2± 8.5	59.2± 8.5	140.1±15.5	393.8±57.2
Fit signal	−8.4±22.3	−1.5± 3.9	−1.2± 3.3	−0.4± 1.0
Total fit	116.2±10.3	238.7±14.5	187.7±12.5	750.2±26.5
On-peak	119.0±10.9	231.0±15.2	176.0±13.3	764.0±27.6

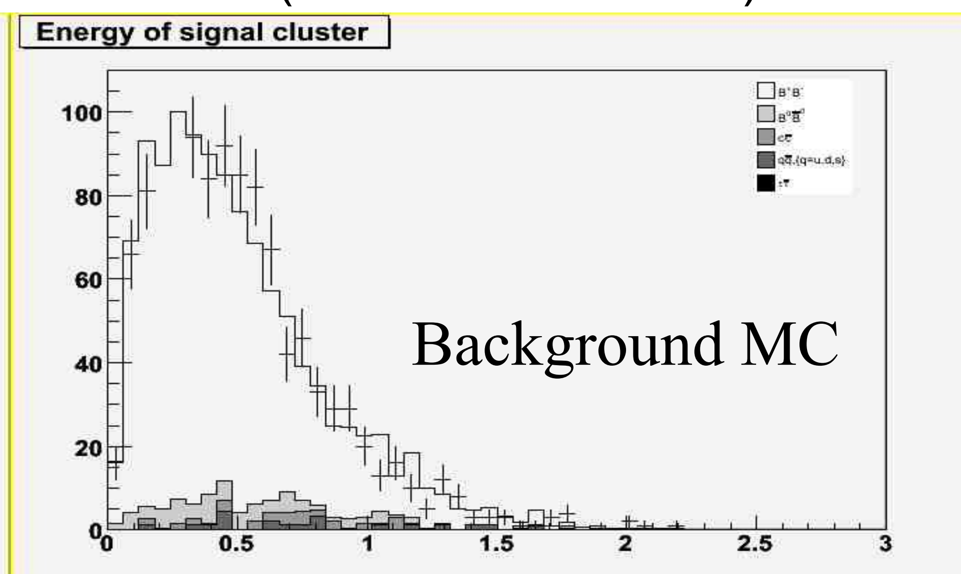
Very challenging analysis! – not clear that inclusive method can easily scale to SuperB luminosity regime

- difficult to model and estimate relevent backgrounds (continuum QED, and b->ulnu)

⇒ Assuming a rate of B($B^+ \to l^+ \nu\gamma$)~1x10^{-6} , expect to see O(10) signal events in 5 ab^{-1} using hadronic tag method

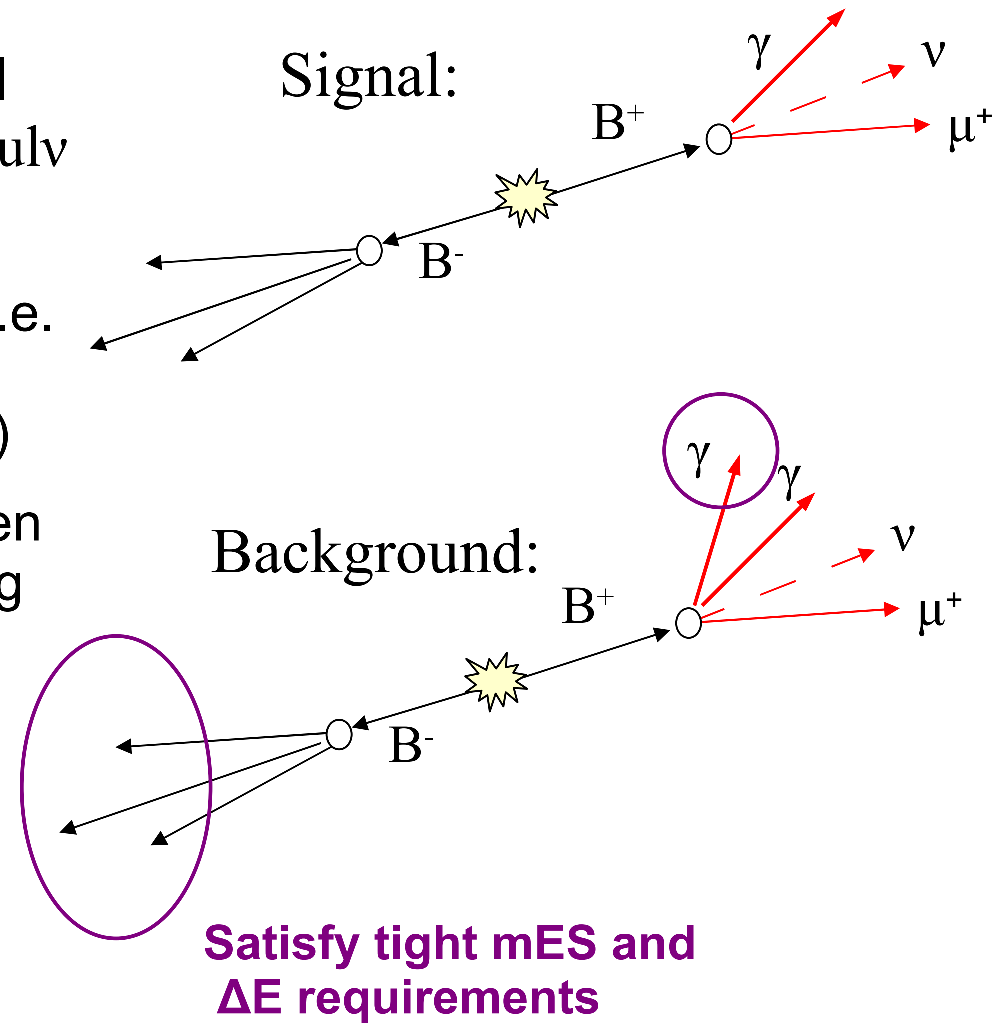
- continuum backgrounds heavily suppressed, and residual background can be estimated from m_{ES} sideband in data (no reliance on MC!)





Tag reconstruction gives additional control over the (dominant) $b \rightarrow u l \nu$ decay background:

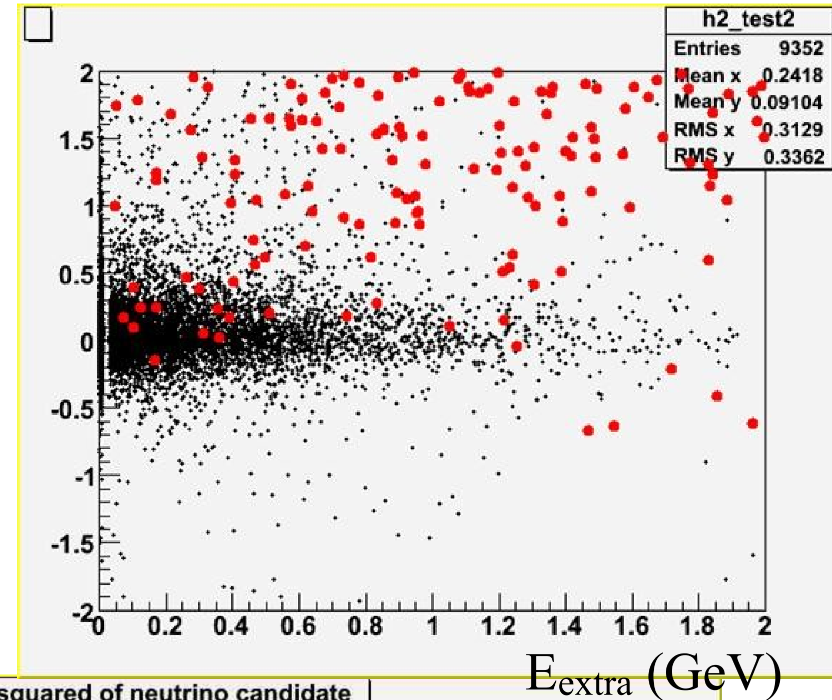
- veto events with lost photons (i.e. missing energy vector pointing outside of detector acceptance)
- improved discrimination between particles associated with the tag and signal candidate B

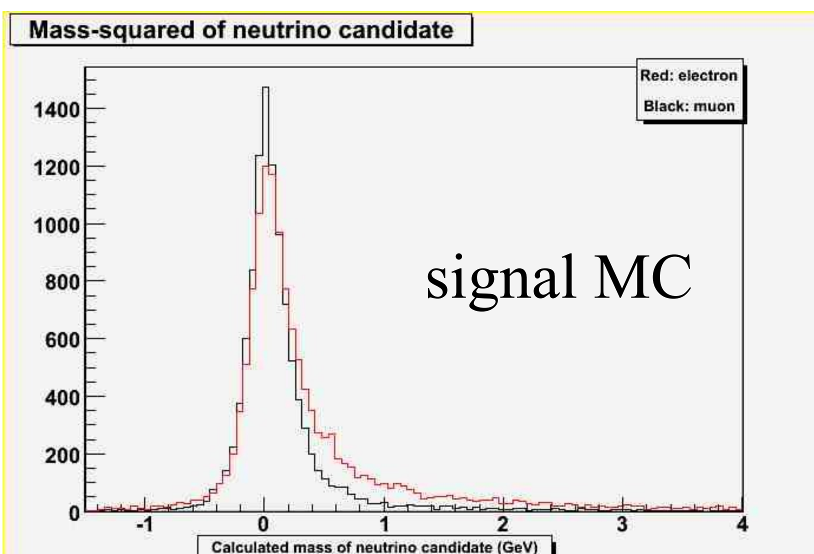


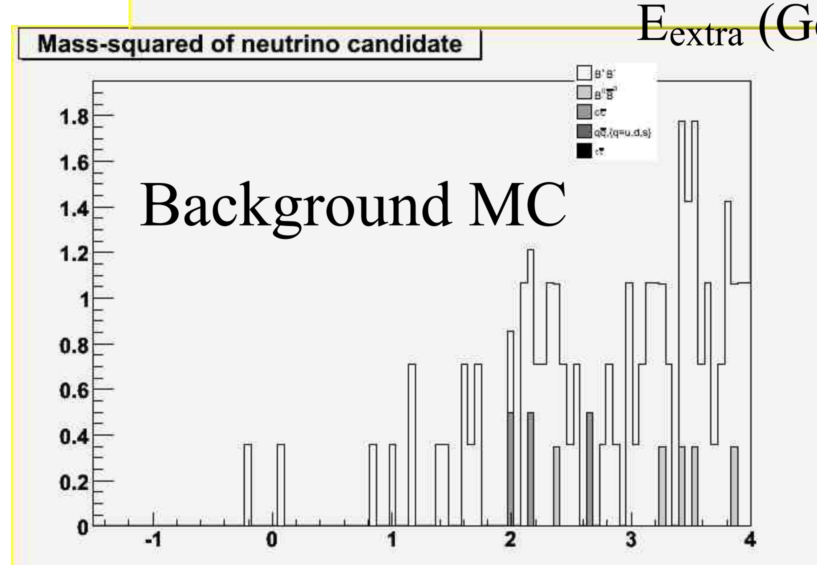
Tagged $B^+ \to l^+ \nu \gamma$ ($l = e, \mu$)

Appears possible to obtain a selection with S/B ~1 over a large region of phase space and with efficiency compatible with observation at SM rate with a few ab^{-1} of data

- detailed studies still in progress, but approach seems promising

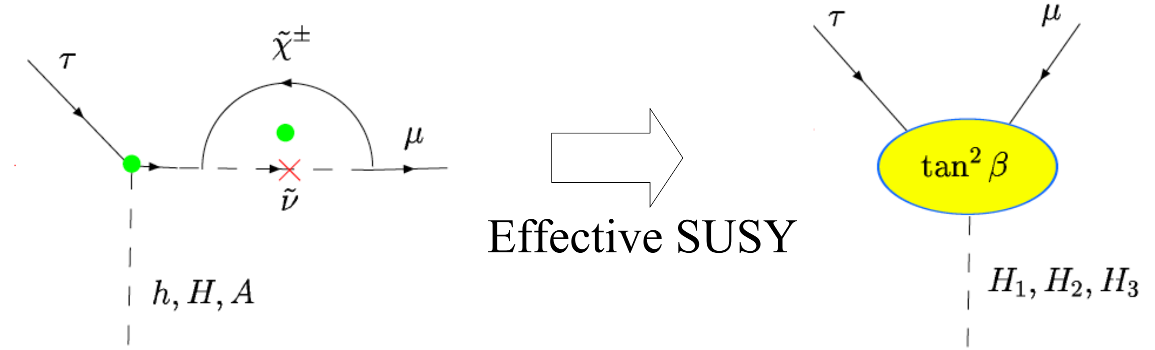




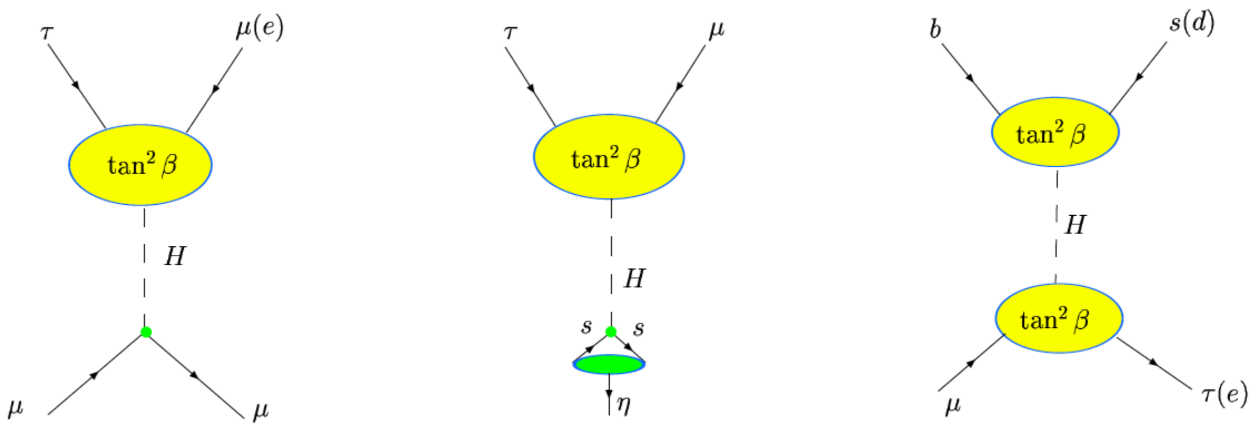


Higgs mediated LFV

Higgs mediated LFV present in MSSM at loop level given that there is a source of LFV among sleptons:



- Predicts LFV effects in a variety of τ and B decay modes (with preference for 3rd generation couplings):



From A. Dedes, Super B Factory proceedings: hep-ph/0503261

Lepton Flavour Violating Modes

"Easy" to do LFV B decay searches for 1st and 2nd generation leptons...

- published along with LFC $\mathbf{B^0} \rightarrow l^+l^-$ and $\mathbf{B} \rightarrow \mathbf{K}l^+l^-$ (l=e,μ) analyses

...but also generally less NP sensitivity than 3rd generation modes*

Two recent BABAR analysis results on LFV B decay modes containing τ leptons:

- $\mathbf{B(\ B^0 \rightarrow e^{+/-}\tau^{-/+}\ )} < 2.8 \times 10^{-5}$ and
- $\mathbf{B(\ B^0 \rightarrow \mu^{+/-}\tau^{-/+}\ )} < 2.2 \times 10^{-5}$ at 90% CL (378M BB pairs)

  arXiv:0801.0697[hep-ex] (Submitted to PRD RC)
- $\mathbf{B(\ B^+ \rightarrow K^+\tau^{-/+}\mu^{+/-}\ )} < 7.7 \times 10^{-5}$ at 90% CL (383M BB pairs)

  Phys. Rev. Lett. 99, 201801 (2007): arXiv:0708.1303[hep-ex]

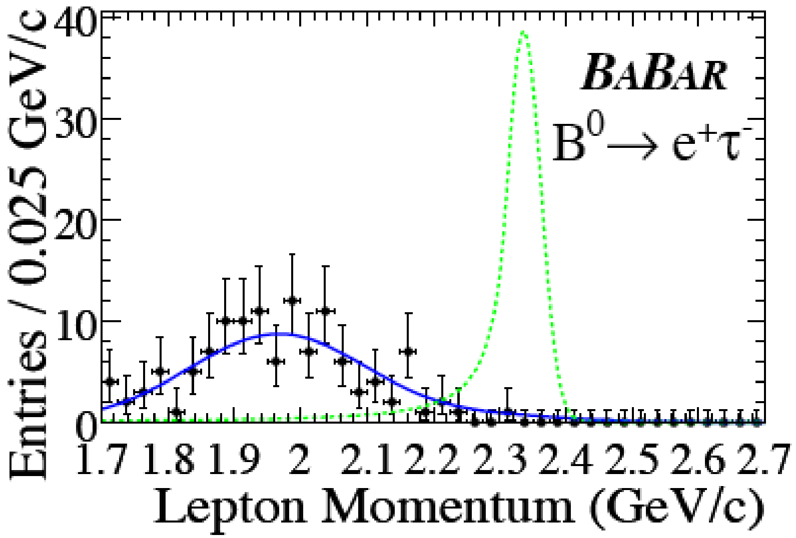
Both use very similar methodology based on hadronic tag reconstruction method...

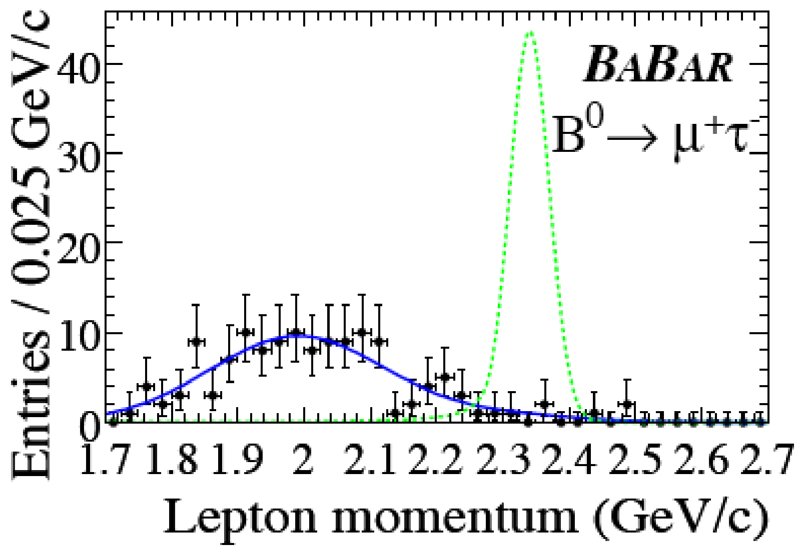
*to the degree that NP is not already ruled out by τ LFV searches

$B^0 \to l^{+/-}\tau^{-/+}$ $(l = e, \mu)$

Analysis is performed simultaneously with hadronic tagged $B^+ \to l^+\nu$ analysis (described previously) using very similar methodology

- key feature is that the non-τ lepton is mono-energetic in the signal B rest frame yielding a clean signature above a relatively smooth background:





- τ reconstruction is straightforward: e, μ, π, ρ, a_1 with appropriate PID and mass contraints (note: know full τ 4-vector!)

Limit not spectacularily better than previous "inclusive" limits (CLEO: Phys. Rev Lett. 93, 241802), but likely the method of choice for SuperB

$B^+ \to K^+ \tau^{+/-} \mu^{-/+}$

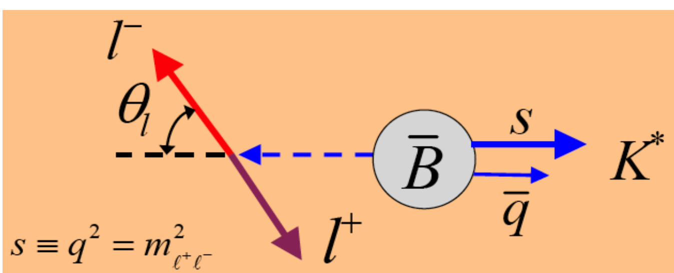
First published result on this mode, which is potentially the most sensitive LFV B decay to NP

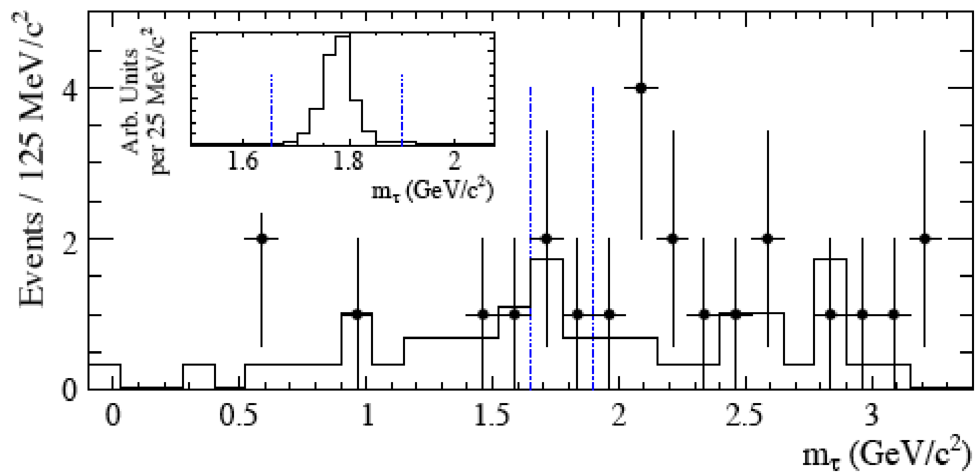
M. Sher and Y. Yuan, Phys. Rev. D44, 1461 (1991)

T. P. Cheng and M. Sher, Phys. Rev. D35, 3484 (1987).

Using tag method, can infer the signal B rest frame and hence (from the K and μ 4-vectors) also the τ 4-vector

- τ mass used to define signal:





Substantial background from $b \to c l \nu$ processes with identical signal topologies:

- **Suppressed by requiring $m(K^+\pi^-) > 1.95$GeV**

Proof-of-concept for these rare decay searches using hadronic tags

- Both $\mathbf{B^+ \to K^+\tau^{-/+}\mu^{+/-}}$ and $\mathbf{B^0 \to \mathit{l}^{+/-}\tau^{-/+}}$ yield a handful of background events in the present analyses ⇒ O(100) for SuperB luminosities and naïve 1/√Lumi scaling of limit
- However, also significant room for selection optimization, so scaling is probably somewhat better

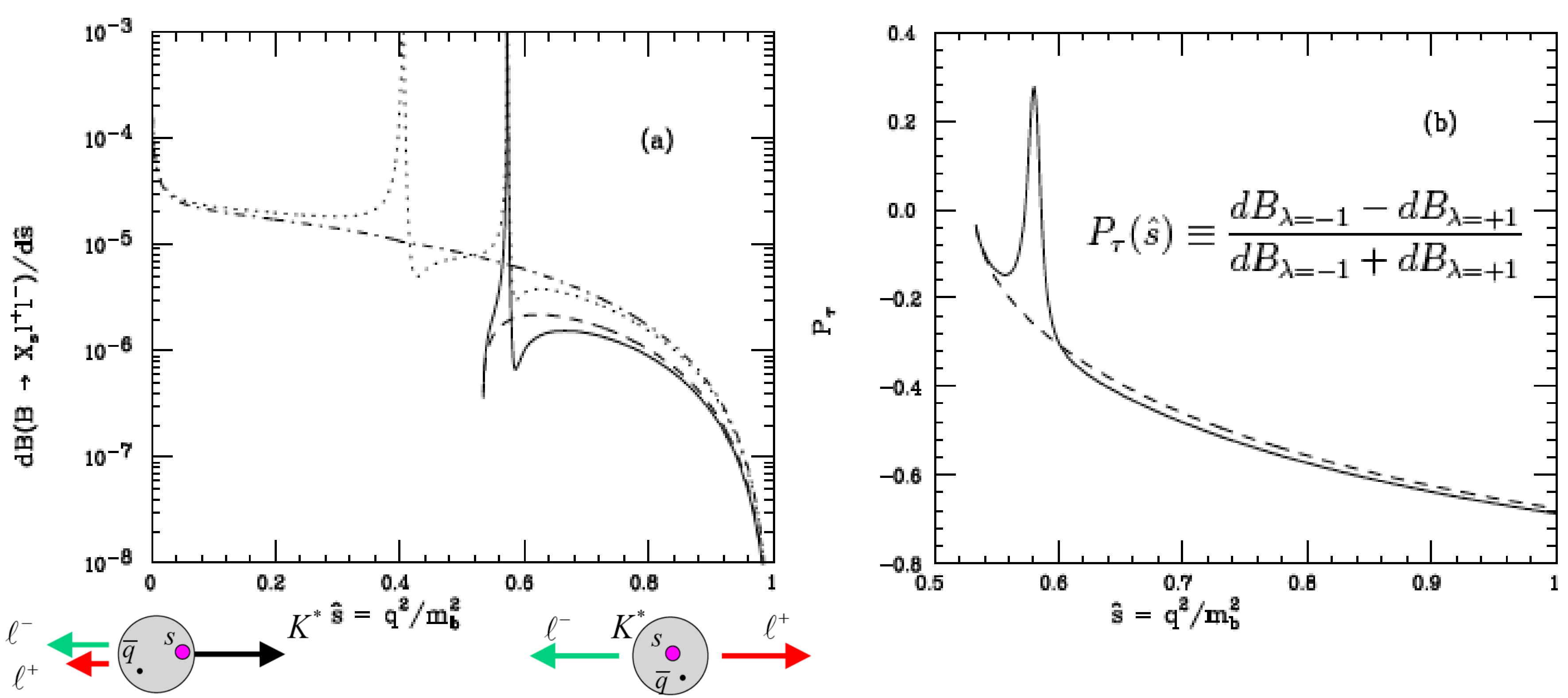
⇒ $\mathbf{B^+ \to K^+\tau^{-/+}\mu^{+/-}}$ is almost $\mathbf{B^+ \to K^+\tau^{-/+}\tau^{+/-}}$ ...

$B \to K^{(*)}\tau^+\tau^-$

J. Hewett, "Tau polarization asymmetry in B ---> X(s) tau+ tau-." Phys.Rev.D53:4964-4969, 1996. (hep-ph/9506289)

- Spires "TOPCITE = 100+" but only two "experimental" references:

  "The BABAR physics book: Physics at an asymmetric B factory"



$B \to K^{(*)}\tau^+\tau^-$

$B(B \to X_s \tau^+\tau^-)$ expected to be comparable to $B(B \to X_s l^+l^-)$ in high q^2 region

- Low q^2 region not kinematically accessible

ℓ	$4x \leq \hat{s} \leq 1$	$0.6 \leq \hat{s} \leq 1$
e	1.2×10^{-5}	8.5×10^{-7}
μ	1.0×10^{-5}	8.5×10^{-7}
τ	5.4×10^{-7}	4.3×10^{-7}

Experimentally, an inclusive determination is essentially impossible, but exclusive $B \to K\tau^+\tau^-$ and $B \to K^*\tau^+\tau^-$ might be possible

- Exclusive $B \to K\tau^+\tau^-$ predicted to be 50-60% of total inclusive rate*, hence the first question is whether we can even potentially observe this...

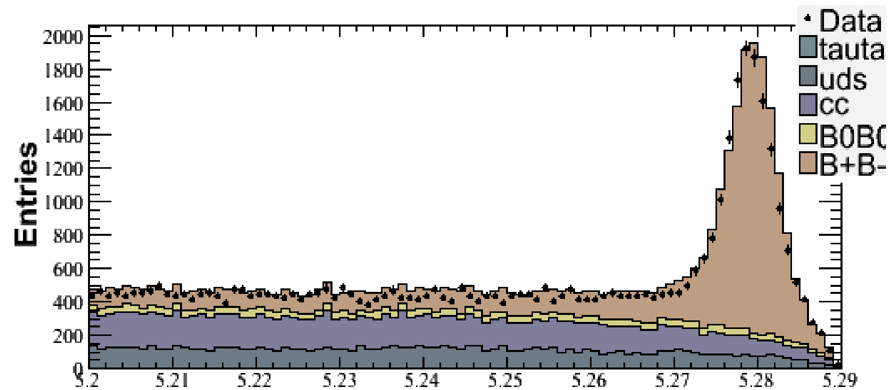
*D. Du, C. Liu, and D. Zhang, Phys. Lett. B317, 179 (1993).

- "Untagged" analysis clearly not feasible:
  - "signature" is a kaon plus two or more electrons, muons or pions (plus possibly some neutrals) with some missing energy and essentially no kinematic information relating them.
- Naively, we are sensitive to this level of BF using hadronic tag method with ~5ab^{-1}

Exclusive $B \rightarrow K^{(*)}\tau^+\tau^-$

Attempt first study to evaluate whether backgrounds in tagged analysis are a show-stopper

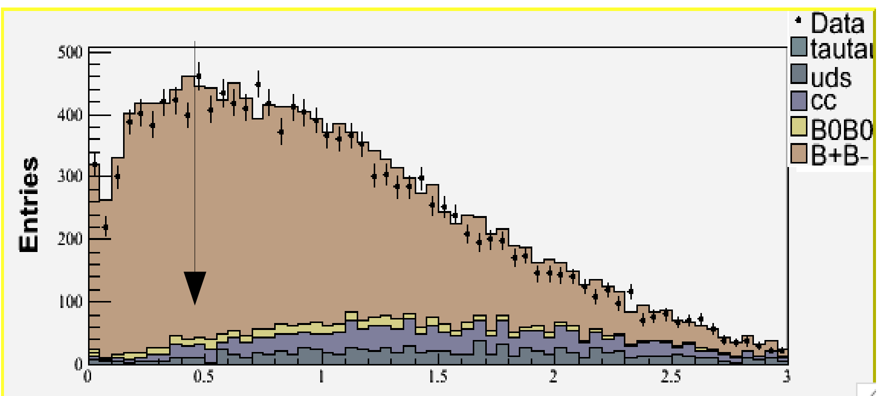
- Hadronic tag analysis would be similar to LFV $B \rightarrow K\tau^+\mu^-$ analysis:



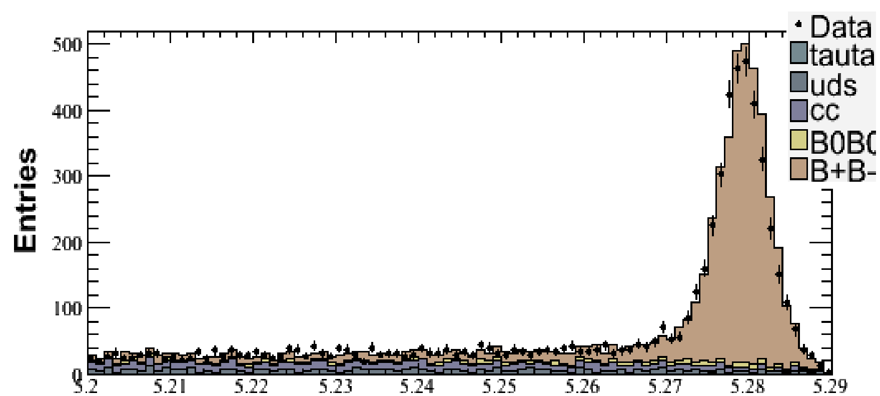
m_{ES} (GeV/c^2)

- Require exactly one identifed $K^{+/-}$ plus two additional charged tracks

- Require that there is little or no additional calorimeter activity



E_{extra} (GeV)



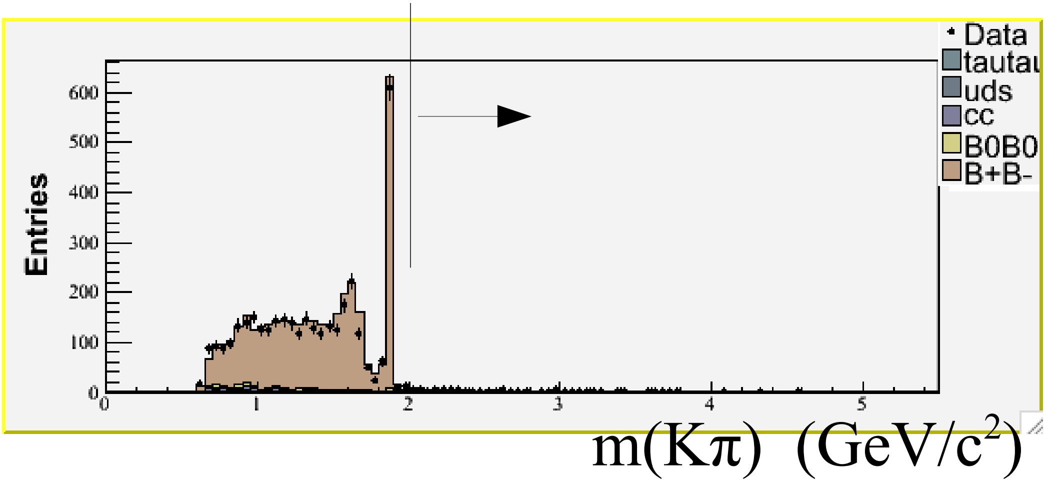
m_{ES} (GeV/c^2)

(All histograms scaled to 113fb^{-1})

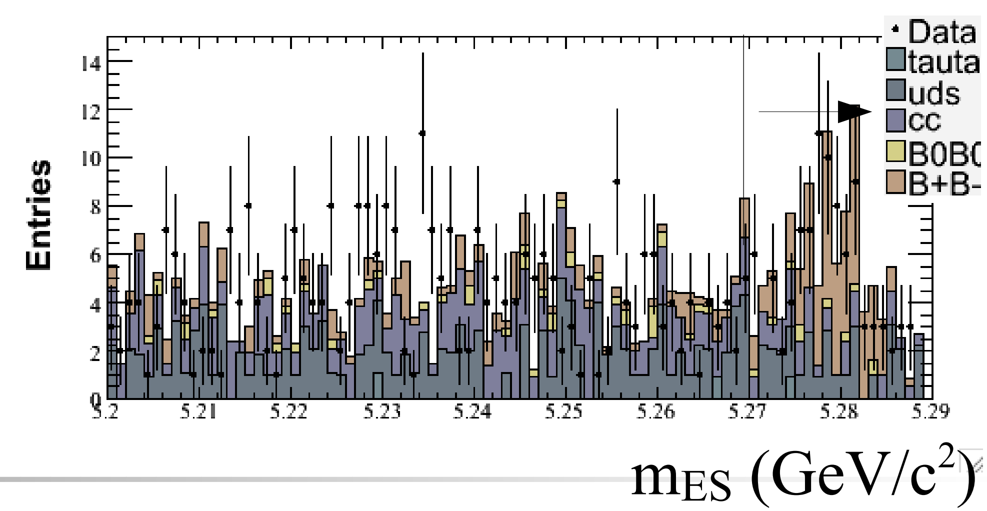
Exclusive $B \to K^{(*)}\tau^+\tau^-$

Anticipate that there will be a substantial background from CKM-favoured B decays: $B \to D^{(*)}X_{had}$ and/or $B \to D^{(*)}\, l\nu$

- Compute invariant mass of $K^{+/-}$ with oppositely charged track (assumed to be a $\pi^{-/+}$):



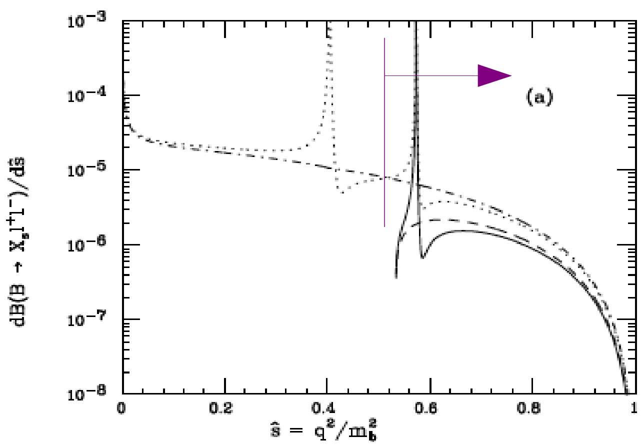
Clear $D^0 \to K\pi$ peak and additional structure visible at lower masses, but relatively little background at higher masses

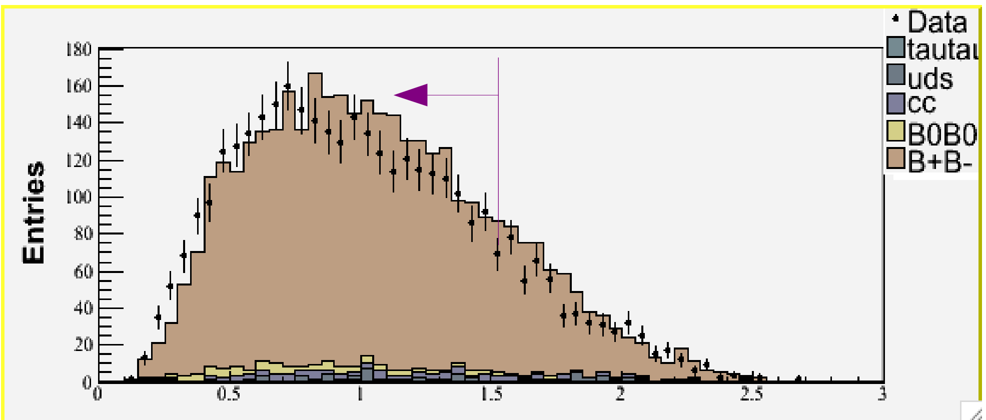


Exclusive $B \to K^{(*)}\tau^+\tau^-$

Large fraction of remaining background has K with momentum beyond kinematic limit for $B \to K\tau^+\tau^-$ signal

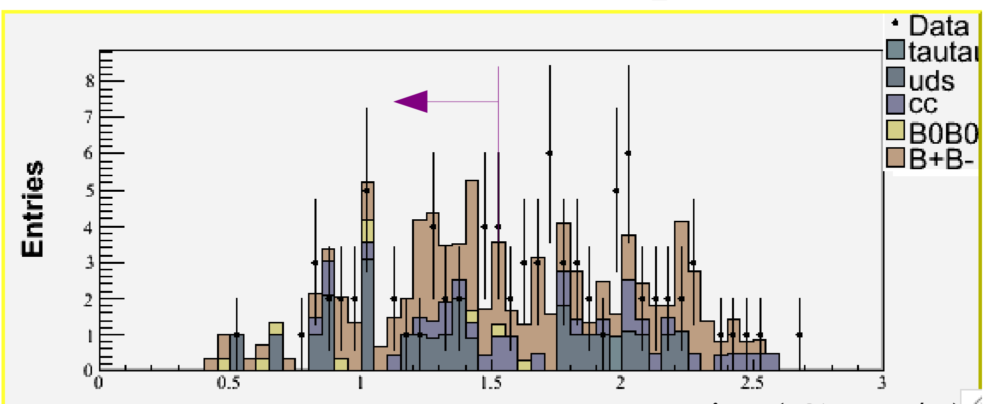
- m(Kπ) veto tends to push the background to higher p*





Kaon p* (GeV/c)

- No selection imposed on τ kinematics, but restricted to e,μ,π modes for the moment
  - ρ, a1 modes could potentially be added later. (Currently lacking signal MC...)

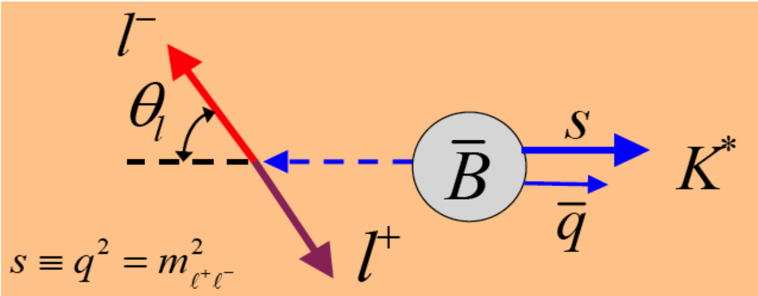


Kaon p* (GeV/c)

Bottom line

Using hadronic tag method, can reduce backgrounds to level of O(100) events per 1ab^{-1} of data with only "topological" cuts plus "charm veto" cut

- SM BF beyond reach of the current B factories, but backgrounds appear remarkably reasonable from initial studies
- τ decay properties can be studied in $\tau^+\tau^-$ rest frame but decay angle has to be inferred from decay products



- Not clear if/how the charm veto biases the polarization asymmetry

Question for theorists: Is this still interesting in light of current (or expected future) $\mathbf{B} \to \mathbf{K}^{(*)} l^+ l^-$ measurements?

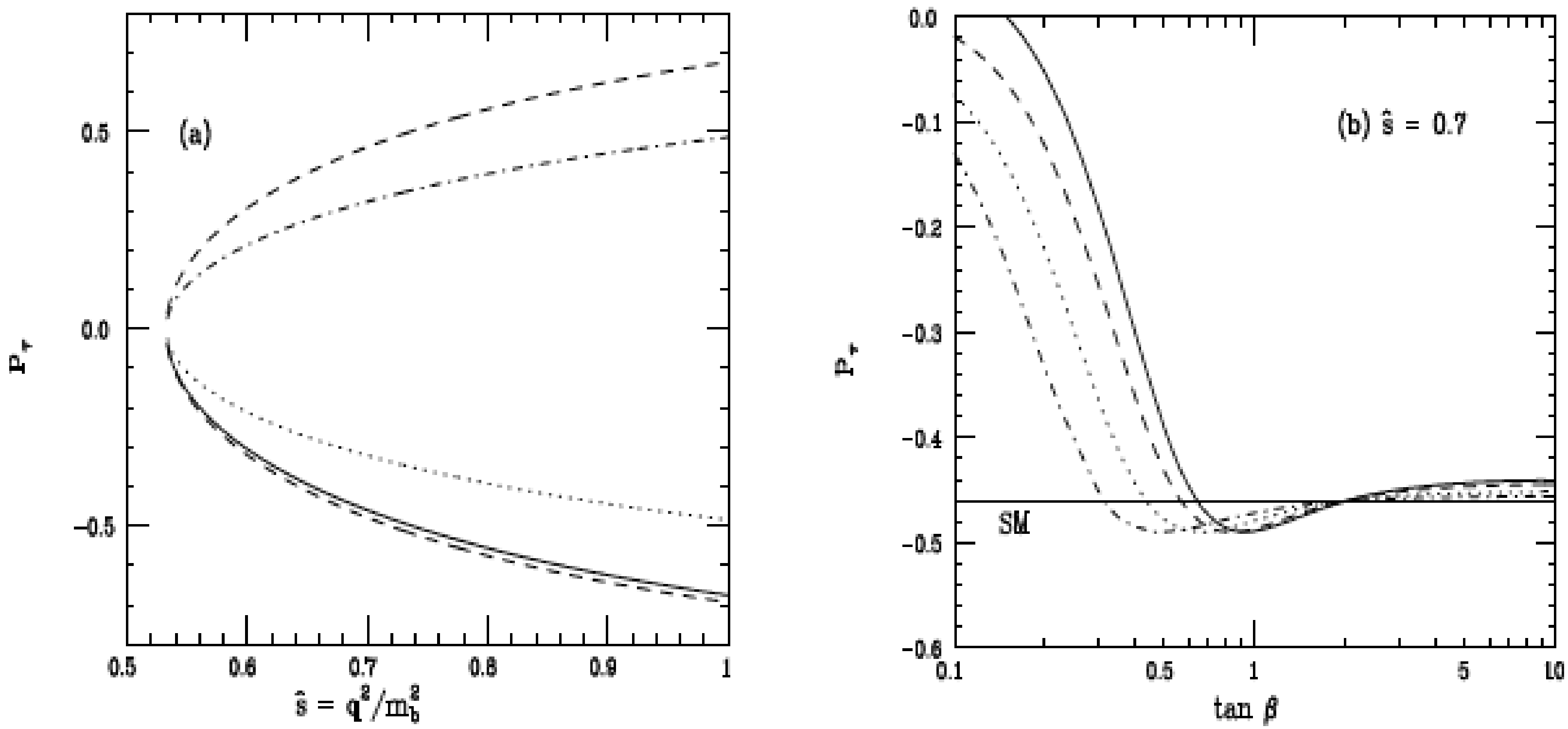
Conclusions

Recent BABAR analyses have demonstrated the feasibility and reach of various rare decay searches using hadronic tag method

- Not necessarily the "best" method, but complimentary to more inclusive methods particularily in cases where there are tricky experimental issues (e.g. poorly modeled backgrounds)
- Both $B^+ \to l^+\nu$ and $B^+ \to l^+\nu\gamma$ could yield reasonably precise branching fraction deteminations with SuperB luminosities
- LVF modes $\mathbf{B^+ \to K^+\tau^{-/+}\mu^{+/-}}$ and $\mathbf{B^0 \to \mathit{l}^{+/-}\tau^{-/+}}$ bounds are likely possible at ~10^{-7} level
- Branching fraction determination of $\mathbf{B \to K\tau^+\tau^-}$ and $\mathbf{B \to K^*\tau^+\tau^-}$ might be possible at SuperB (at very least a fairly stringent limit could be obtained). Polarization asymmetry etc needs further study...

$B \to X_s \tau^+ \tau^-$ Polarization Asymmetry

J. Hewett, Phys.Rev.D53:4964-4969, 1996. (hep-ph/9506289)



Tau polarization asymmetry (a) with changes in the sign of the Wilson coefficients at the electroweak scale, corresponding to C10, C9,10, C9, SM C7,8 from top to bottom; (b) in two-Higgs-doublet models as a function of tan with mH± = 50, 100, 250, 500 corresponding to the solid, dashed, dotted, and dash-dotted curves, respectively. The SM value is denoted by the solid horizontal line.

$B^0 \to \tau^+\tau^-$

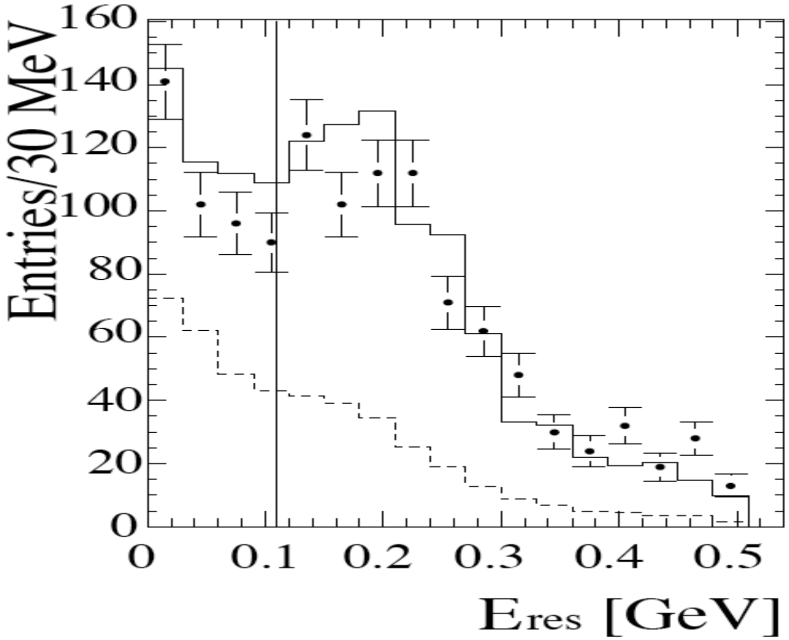
Is not a particularly good prospect for New Physics in spite of the optimism of certain theorists...

- Only limit to date is from BABAR (PhD thesis of Chris Potter, Oregon):

$Br(B^0 \to \tau^+\tau^-) < 3.2\times10^{-3}$ (90%CL)

PRL 96 241802 (2006)

(SM expectation is $\sim 1\times10^{-7}$)



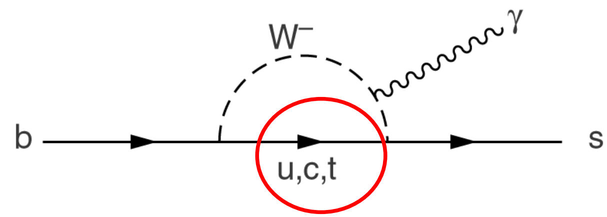
- hadronic tagged analysis using neural net selection (Run 1-4 data)
  - with 254 events observed in the signal region

Issue is irreducible background from $b \to c$ containing a K_L and (usually) one or more leptons

- Unlike backgrounds for $B \to \tau\nu$, these are large Br processes and do not require particles passing outside of detector acceptance
- Naïve scaling to $1 ab^{-1}$ yields $\sim 1.5\times10^{-3}$ but I doubt we will find a willing victim to do the analysis...

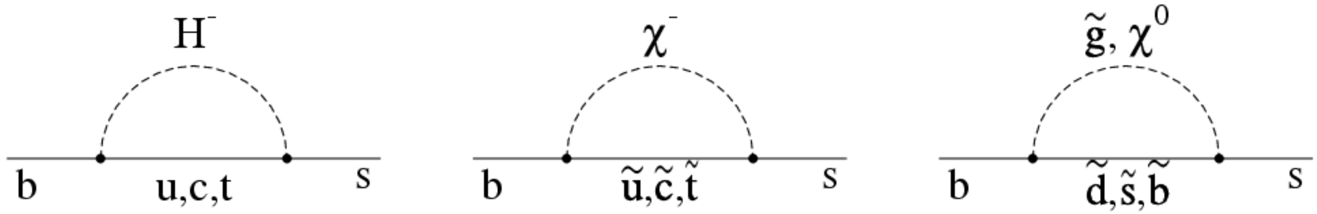
FCNC decays

Flavour changing neutral current (FCNC) processes do not occur in SM at tree level



SM dominated by t-quark contribution

- Loop-mediated processes can have large contributions from non-SM diagrams of same order as leading SM contributions:



Low-energy effective Hamiltonian for b →s (or d) transitions:

$$\mathcal{H}_{\rm eff} = -\frac{4G_F}{\sqrt{2}} V_{ts}^* V_{tb} \sum_{i=1}^{10} C_i(\mu)\, O_i(\mu)$$

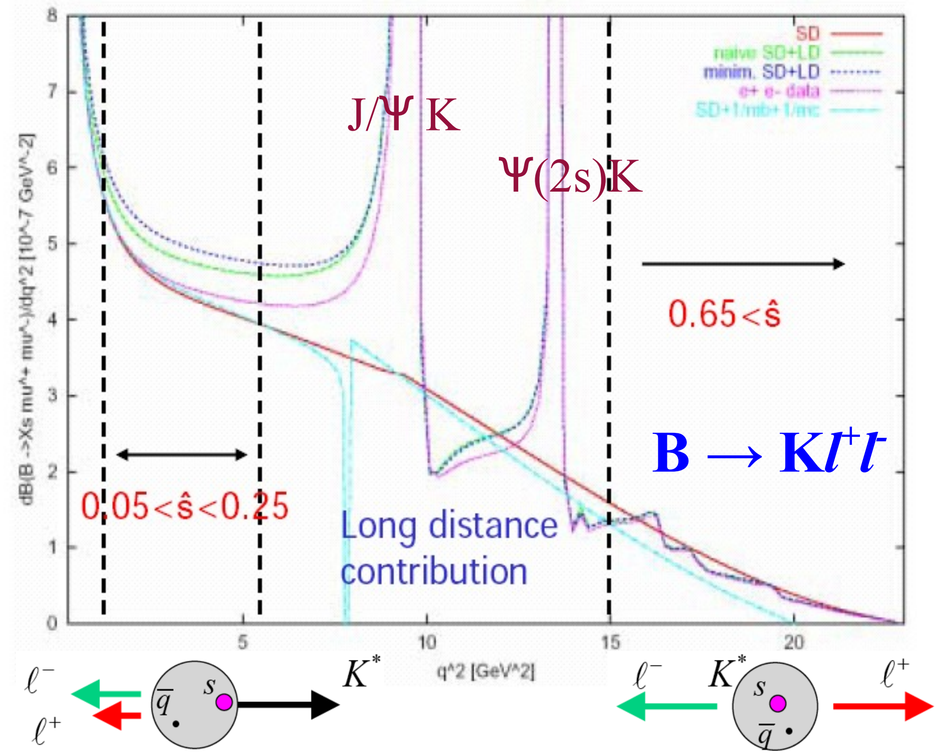
Products of field operators (nonperturbative hadronic matrix elements; HQE in inverse powers of m_b)

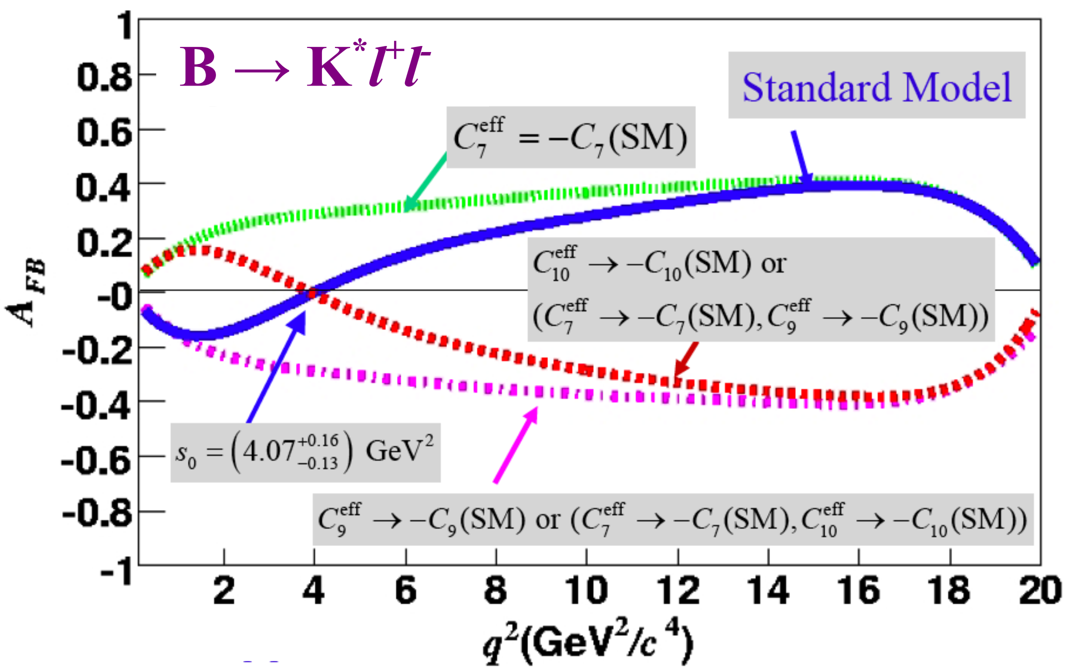
Wilson coefficients (calculated perterbatively; encode short-distance physics)

- New Physics can enter via non-SM values of Wilson coefficients

$B \to K^{(*)} \ell^+ \ell^-$

- $B \to K^{(*)} \ell^+ \ell^-$ receives contributions from C_7 (photon penguin), C_9 (vector EW) and C_{10} (axial-vector EW)
  - Also substantial long-distance contributions (J/Ψ K and $\Psi(2s)$K)

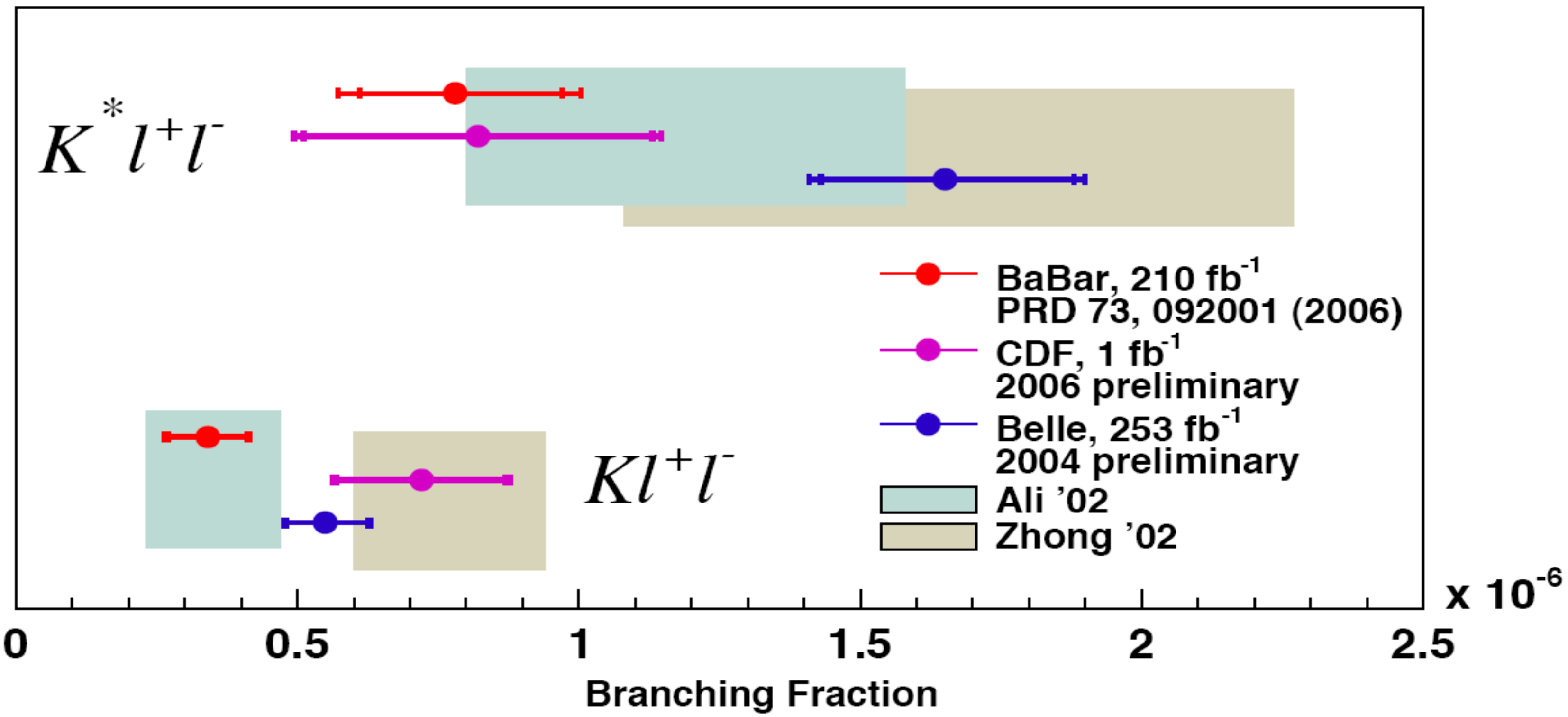




Interference between contributing amplitudes produces asymmetries in lepton angular distribution

- A_{FB} sensitive to non-SM values of Wilson coefficients

$B \rightarrow K^{(*)} l^+ l^-$ Branching Fractions



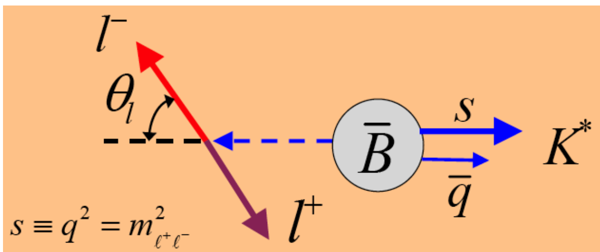
BABAR (209 fb^{-1}) PRD 73, 092001 (2006)

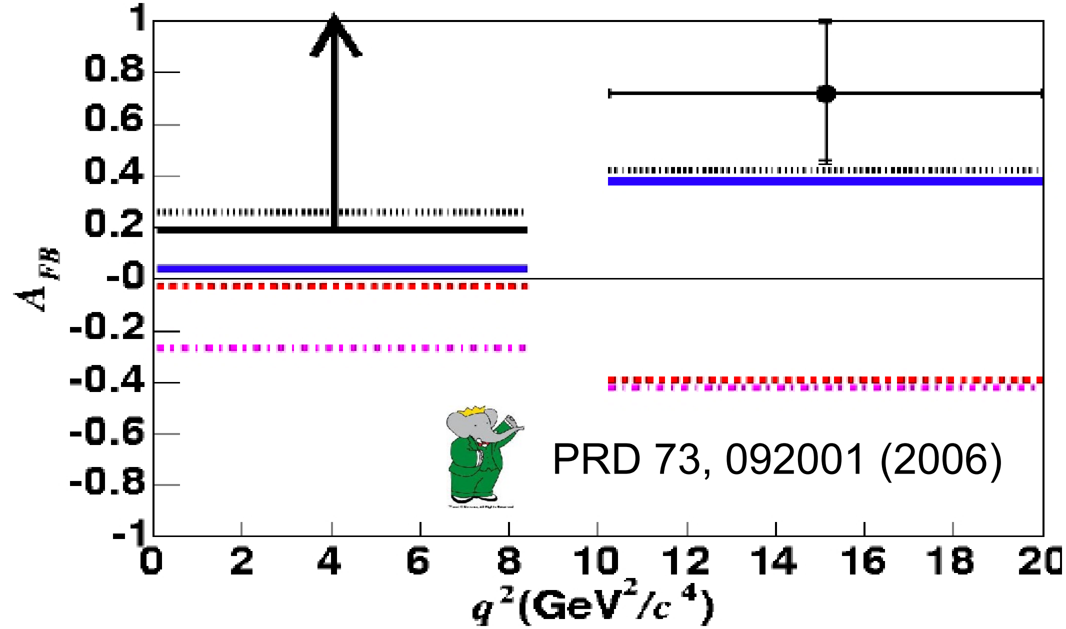
$$B(B \rightarrow K l^+ l^-) = (0.34 \pm 0.07 \pm 0.02) \times 10^{-6} \quad (6.6\sigma)$$

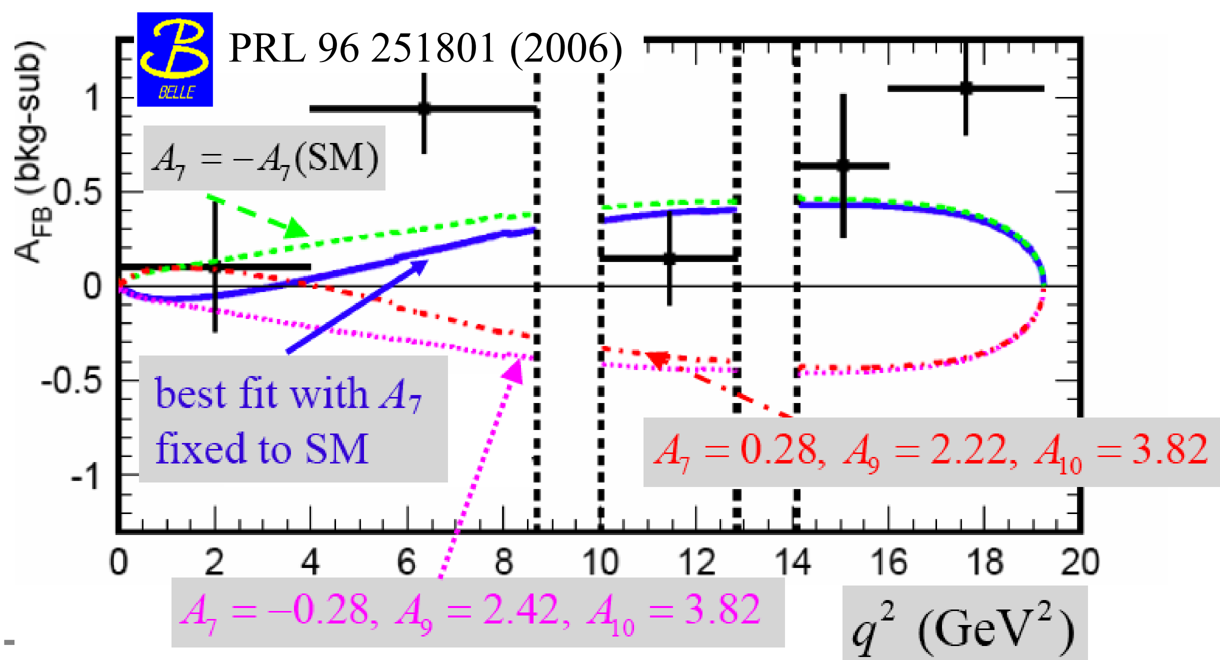
$$B(B \rightarrow K^* l^+ l^-) = (0.78\,^{+0.19}_{-0.17} \pm 0.11) \times 10^{-6} \quad (5.7\sigma)$$

Determination of A_{FB}

First determinations of A_{FB} in bins of q^2 with sensitivity to Wilson coefficients:





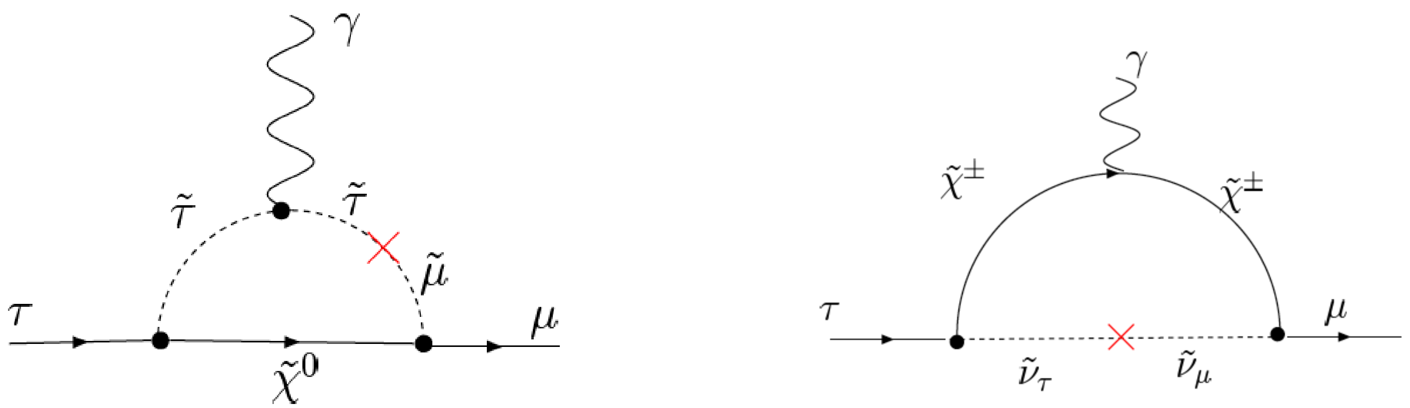


- Belle and BABAR results both favour SM value for C_{10} (high q^2) but less consistency with SM in low q^2 region

Lepton Flavour Violation

In Standard Model, lepton flavour conservation is not associated with any underlying symmetry principle

- LFV generally permitted in New Physics models containing more than one Higgs doublet
  - In SUSY seesaw models, flavour changing insertions arise from Yukawa couplings in the slepton mass RGEs:



⇒ New Physics effects in $\tau \to l\,\gamma$ (l = e,μ) can saturate experimental bounds in natural and well-motivated models

- MSSM with heavy right-handed neutrinos and seesaw mechanism: Br~10^{-7}
- heavy Dirac neutrinos, RPV SUSY models, flavour changing Z' models...