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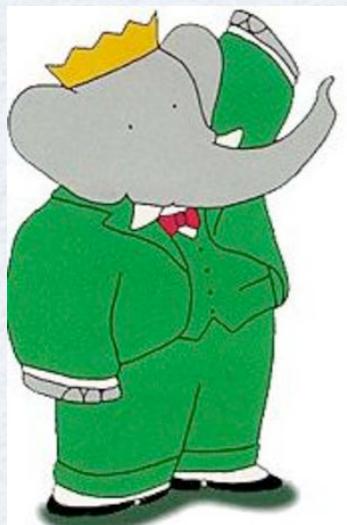


now at UC Irvine



Rare Decays at B-Factories

Recontres de Moriond EW 2009
La Thuile, March 7th-14th 2009



On behalf of the BaBar & Belle Collaborations



Rare Decays

- The SM has been able to explain in coherent framework (almost) all the experimental evidence of weak, strong and electromagnetic interactions
- CKM picture has been able to explain all the measurements in flavour sector
- **BUT** we know this is not the ultimate theory
- Everybody is eager for New Physics:
 - Explore energy frontiers (Tevatron, LHC)
 - Measure precisely virtual processes which can test high energy scales
- Rare decays provide many clean probes:
 - If a suppressed decay is observed, clear sign of NP
 - If an UL is set, NP scenarios are constrained

Complementary
approaches

Outline

From the (SM expected) less rare to the rarest.....

• $B^\pm \rightarrow \tau^\pm \nu$

$\tan\beta$ vs m_{H^\pm}

• $B \rightarrow h^{(*)} \bar{\nu}\nu$

Dark Matter/SUSY

• $B^\pm \rightarrow l^\pm \nu$ ($l = e, \mu$)

LFV (& $\tan\beta$ vs m_{H^\pm})

• $B^0 \rightarrow J/\psi \phi$

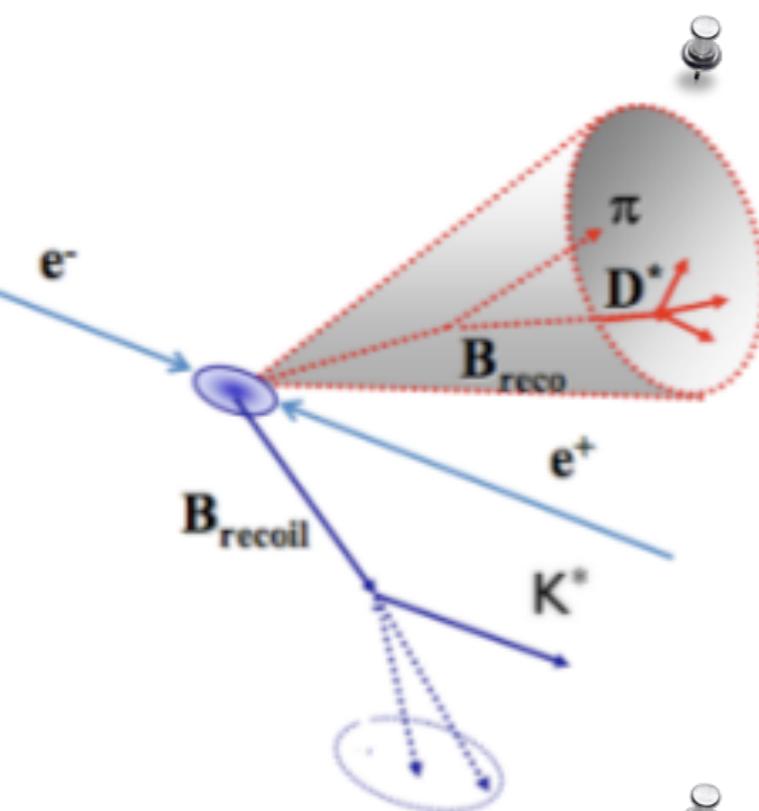
Rescattering effects

• $B^\pm \rightarrow K^\mp \pi^+ \pi^- / K^+ K^- \pi^\mp$

$b \rightarrow d d \bar{s}$ & $b \rightarrow s s \bar{d}$

Analyses Overview

- Analyses with undetectable particles from signal B decay:



- Recoil technique: low efficiency (1% - 0.1%) but HIGH resolution--> necessary when more than one neutrino is present
- Semileptonic tagged recoil: higher efficiency but lower purity
- Hadronic tagged recoil: lower efficiency but higher purity
- Totally inclusive reconstruction exploiting kinematic constraints: HIGH efficiency but low resolution

$$B^\pm \rightarrow \tau^\pm \nu / B \rightarrow h^* \nu \nu$$

$$B^\pm \rightarrow l^\pm \nu \quad (l=e, \mu)$$

- Analyses with all detectable particles from signal B decay:

- Full kinematical reconstruction of the event possible

$$B^\pm \rightarrow K^\mp \pi^+ \pi^- / K^+ K^- \pi^\mp$$

$$B^0 \rightarrow J/\psi \phi$$

$b \rightarrow s \gamma \gamma$

FCNC standard probe for $\text{NP} \leftrightarrow \text{forbidden at tree level in SM}$

$$\mathcal{B}(B \rightarrow K^* \nu \bar{\nu})|_{\text{SM}} = (6.8^{+1.0}_{-1.1}) \times 10^{-6}$$

$$\mathcal{B}(B \rightarrow K \nu \bar{\nu})|_{\text{SM}} = (4.5 \pm 0.7) \times 10^{-6}$$

Altmannshofer et al.
arXiv:0902.0160

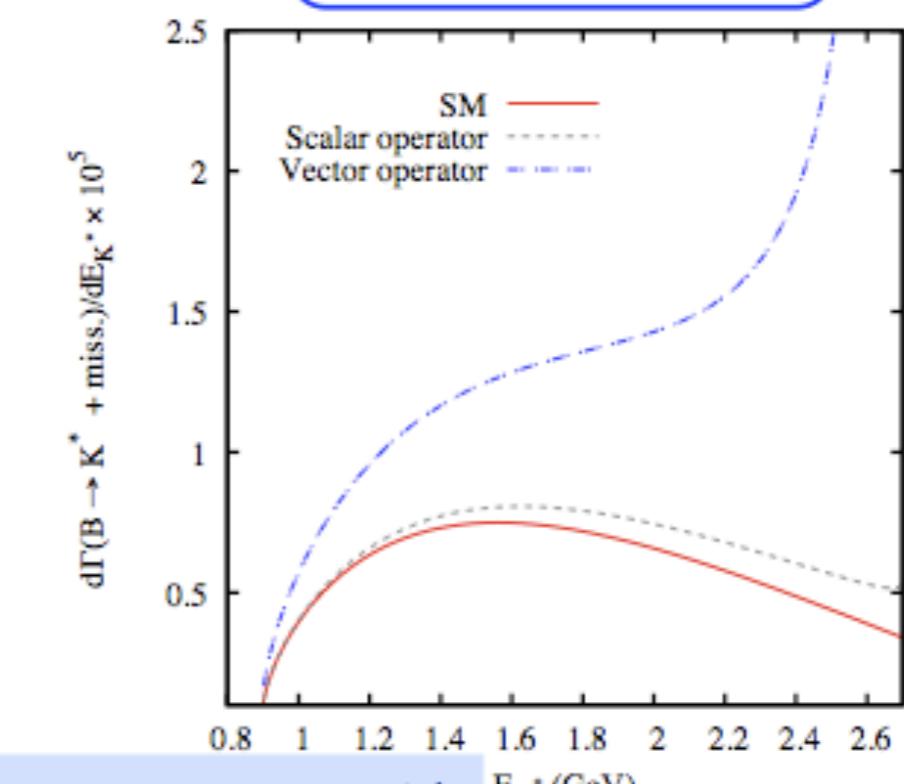
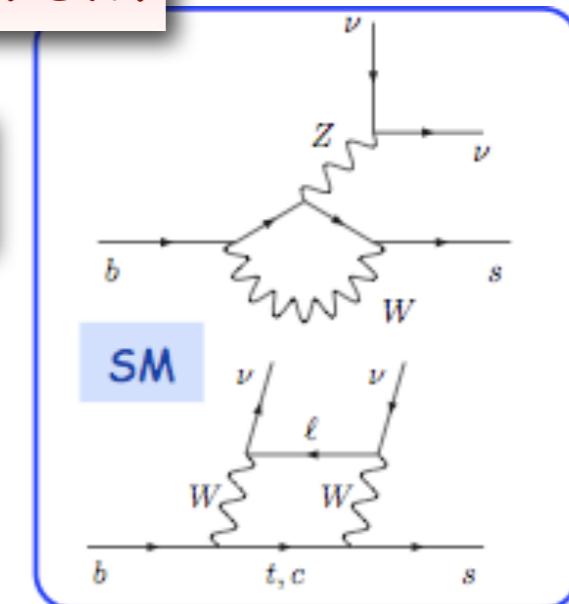
- * $\Delta F = 1$ transitions via one-loop box or electroweak penguin diagrams
- * NP can enter through several exotic scenarios

- * Non-Standard Z Couplings
- * Unparticle Physics
- * Light Dark Matter

G. Buchalla et al,
PRD 63, 014015
T.M.Aliev et al
arXiv:0705.4542
C. Bird et al
PRL 93, 201803

- * SUSY, Unparticle etc. can strongly affect the kinematic in terms of $s_{vv} = m_{vv}^2 / m_B^2$

Theoretical calculations for these processes particularly reliable due to the absence of long distance interactions which affect $B \rightarrow h^* ll$



K^* energy spectrum with unparticles

$B \rightarrow h^{(*)} \nu \bar{\nu}$ analysis

492 fb^{-1}

- $h = K^+, K_S^0, K^{*0}, K^{*+}, \pi^+, \pi^0, \rho^+, \rho^0$



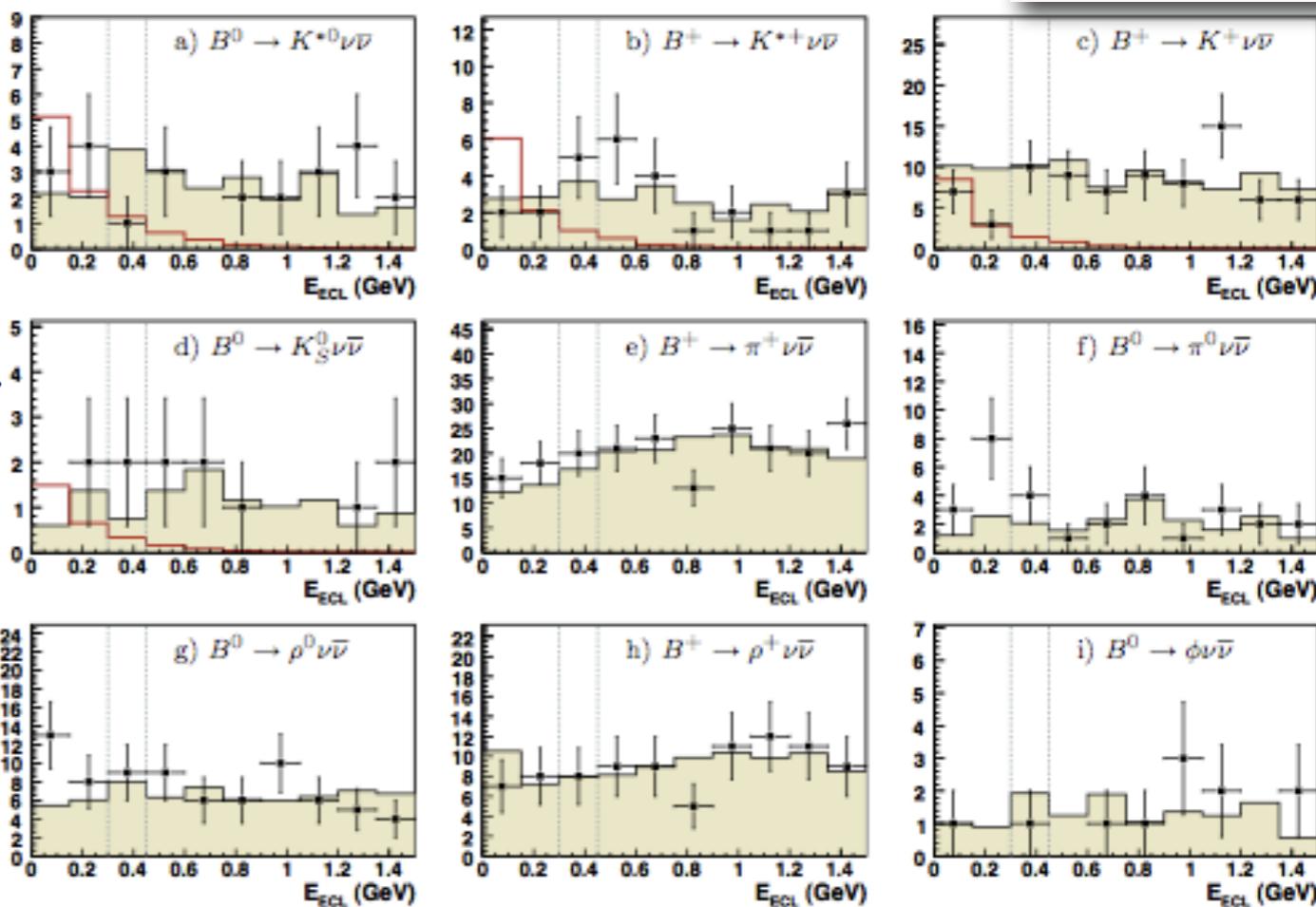
- Hadronic recoil

- B_{sig} selected with $E_{\text{ECL}} = E_{\text{tot}} - E_{\text{reco}} < 0.3 \text{ GeV}$

- (Standard) Model dependence introduced applying cuts on signal h^* kinematics

- Cut & count yield extraction

- Feldman-Cousins UL extraction @ 90% CL



PRL 99, 221802

$K^{*0} \nu \bar{\nu} < 3.4 \times 10^{-4}$
$K^{*+} \nu \bar{\nu} < 1.4 \times 10^{-4}$
$K^+ \nu \bar{\nu} < 1.4 \times 10^{-5}$
$K^0 \nu \bar{\nu} < 1.6 \times 10^{-4}$

Mode	N _{obs}	N _{bkg}	eff(x 10 ⁻⁵)
$K^{*0} \nu \bar{\nu}$	7	4.2 ± 1.4	5.1 ± 0.3
$K^{*+} \nu \bar{\nu}$	4	5.6 ± 1.8	5.8 ± 0.7
$K^+ \nu \bar{\nu}$	10	20.0 ± 4.0	26.7 ± 2.9
$K^0 \nu \bar{\nu}$	2	2.0 ± 0.9	5.0 ± 0.3

B \rightarrow K * ν ν analyses

413 fb $^{-1}$

- No model dependent cuts on K * kinematic

First completely model independent analyses!!

- Most important variable E_{extra} SL: ML fit to E_{extra} distribution

- HAD: fit to NN output

NN variables: R₂, cosθ_{Btag/T}, E_{miss} + p_{miss}, cosθ_{miss}, M_{K*}, M_{Ks}, E_{extra}

- HAD and SL results combined

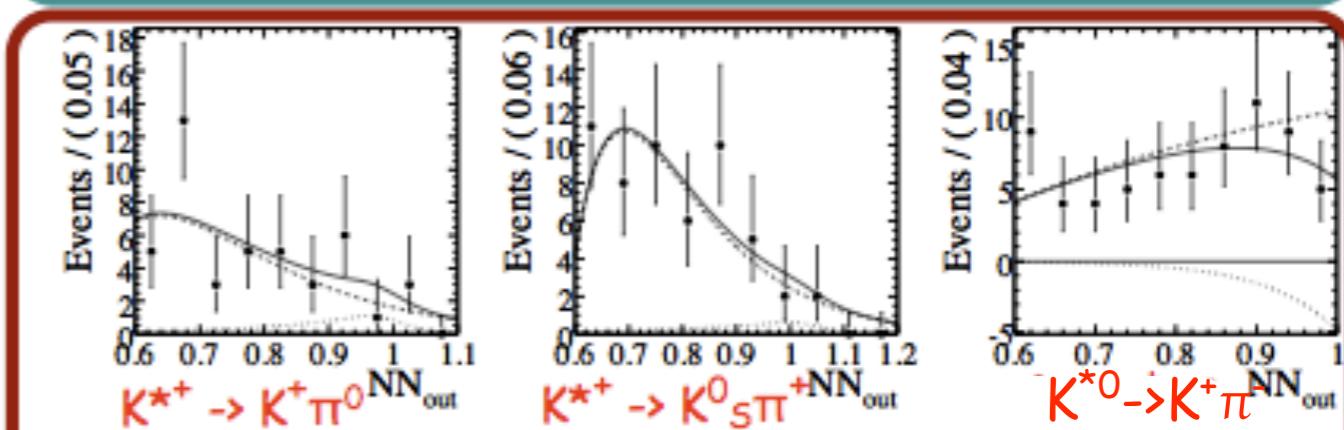
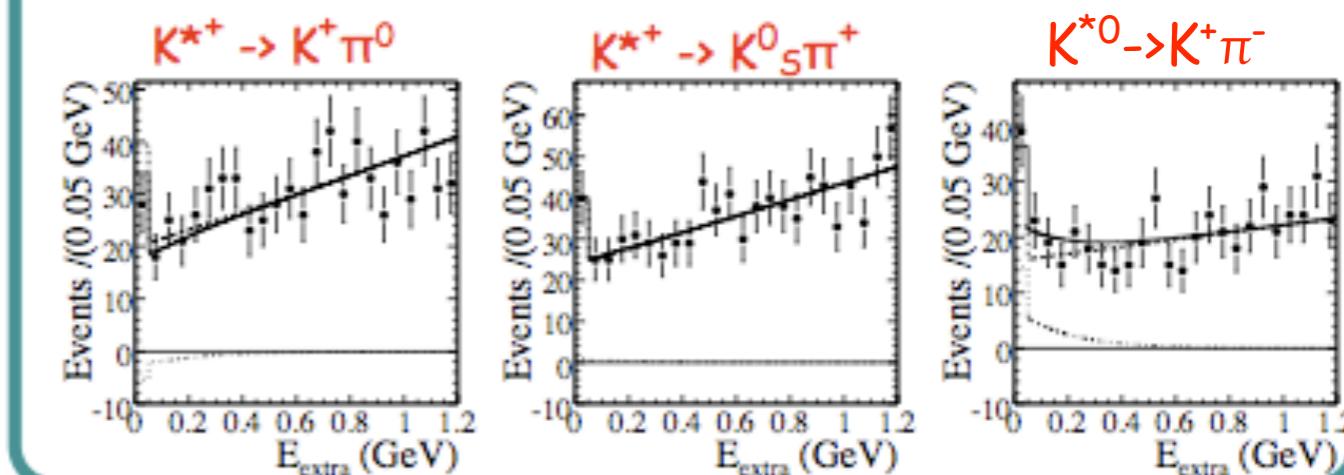
- UL extraction in Bayesian approach @ 90% CL

	SL	HAD
K $^{*0} \nu \nu$	< 18 × 10 $^{-5}$	< 11 × 10 $^{-5}$
K $^{*+} \nu \nu$	< 9 × 10 $^{-5}$	< 21 × 10 $^{-5}$

Combined

K $^{*0} \nu \nu$	< 12 × 10 $^{-5}$
K $^{*+} \nu \nu$	< 8 × 10 $^{-5}$
K $^* \nu \nu$	< 8 × 10 $^{-5}$

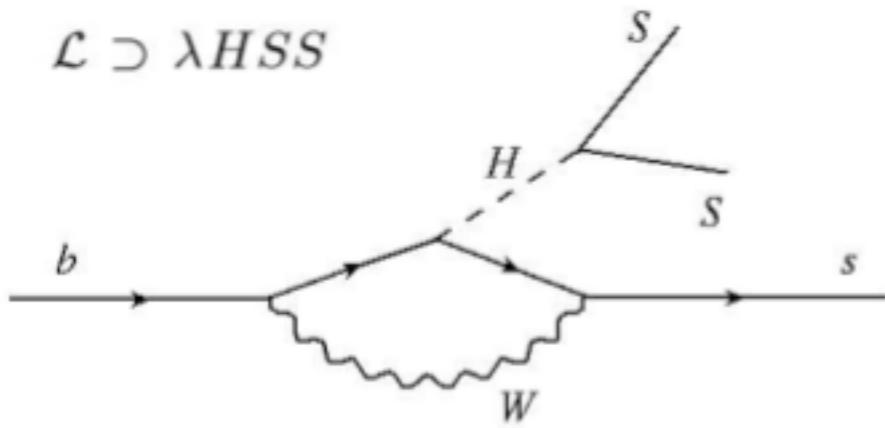
E _{extra}	Fit Results	N _s	-22 ± 16 ± 14	3 ± 17 ± 15	35 ± 13 ± 9
		N _b	754 ± 32	869 ± 34	476 ± 25
		ε (×10 $^{-4}$)	5.6 ± 0.7	4.3 ± 0.6	6.9 ± 0.8
		N _{BB} (×10 6)		454 ± 5	
		UL (90% CL)	18 × 10 $^{-5}$		9 × 10 $^{-5}$



	NN Fit Results	N _s	5 ± 6 ± 4	3 ± 7 ± 4	-10 ± 9 ± 6
		N _b	39 ± 9	51 ± 10	77 ± 13
		ε _{B,sig} (×10 $^{-2}$)	5.8 ± 0.5	5.2 ± 0.6	16.6 ± 1.4
		N _{B,had} (×10 5)	10.128 ± 0.010 ± 0.344	7.175 ± 0.008 ± 0.222	
		UL (90% CL)	21 × 10 $^{-5}$		11 × 10 $^{-5}$

Limits on Dark Matter

- Let's suppose there is a light (< 2.5 GeV) scalar dark matter candidate S



- The UL can be translated into S mass & coupling constraint

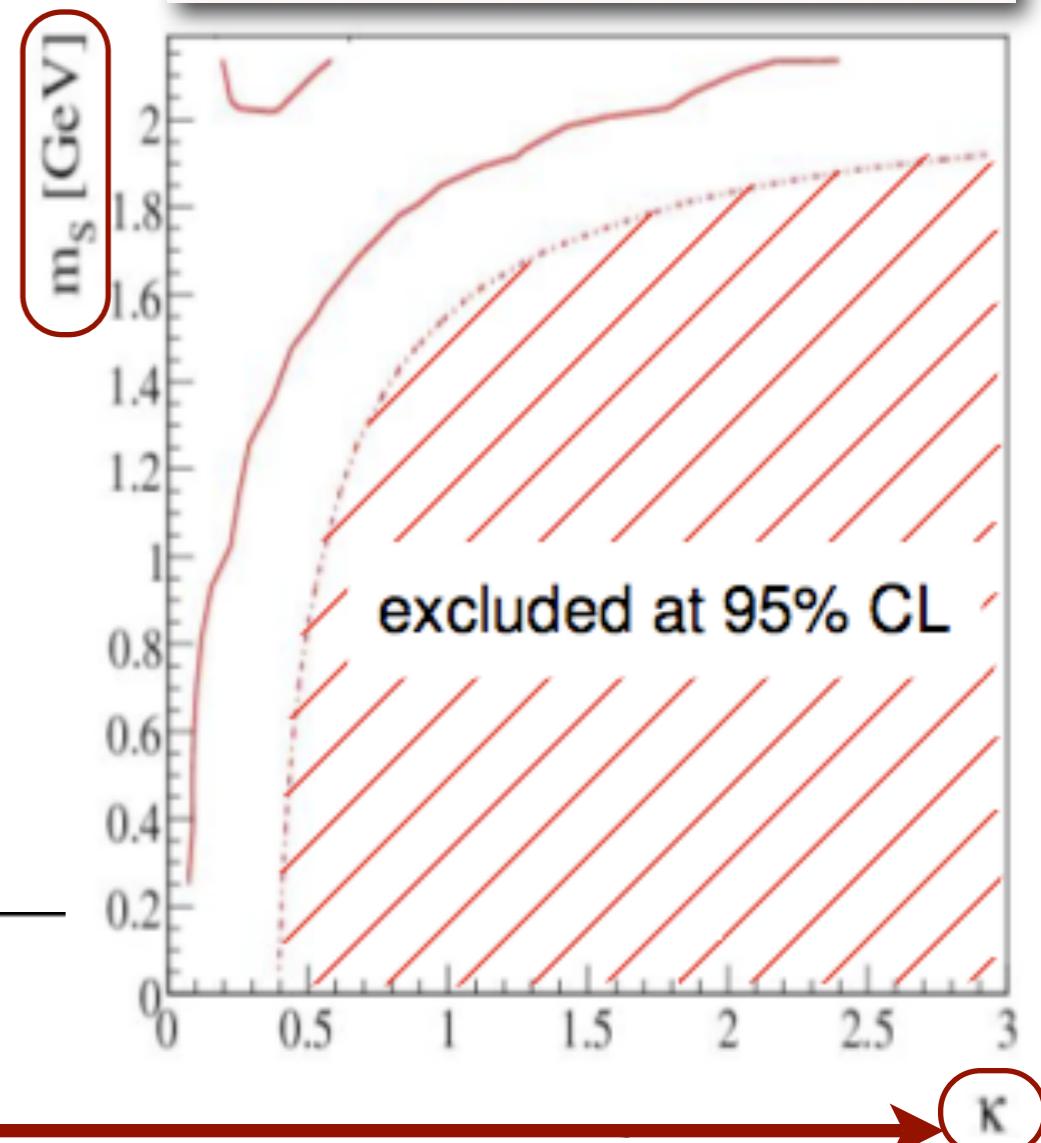
N.B. the $H \rightarrow SS$ decay would saturate the Higgs decay rate, making impossible the Higgs discovery at LHC!!

Burgess et al.
Nucl.Phys. B619, 709

$$\kappa^2 = \lambda^2 \left(\frac{100 \text{ GeV}}{m_h} \right)^4$$

$\sim O(1)$ from cosmological constr.

From BaBar UL
(using for SM Buchalla, Hiller & Isidori PRD 63, 014015)



See A. Bozek's talk
for Belle results
on $B \rightarrow \tau \nu$

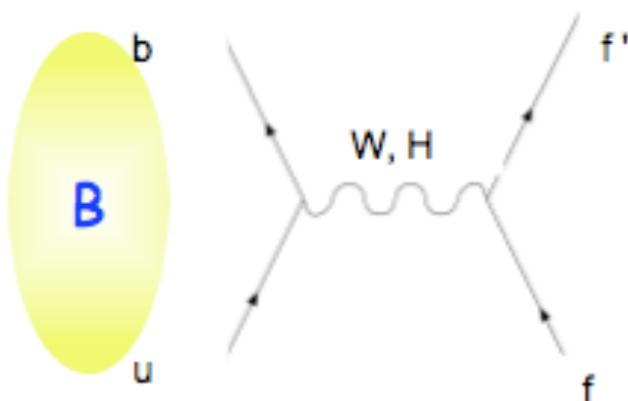
$B^\pm \rightarrow l^\pm \nu$

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

$$\tau \nu = (1.2 \pm 0.4) \times 10^{-4}$$

$$\mu \nu = (5.6 \pm 0.4) \times 10^{-7}$$

$$e \nu = (1.3 \pm 0.4) \times 10^{-11}$$



Annihilation process : helicity suppression allows charged Higgs to be competitive with SM
Directly test Yukawa interactions

* In a general SUSY scenario

$$\frac{\mathcal{B}(B^+ \rightarrow l^+ \nu_l)_{\text{exp}}}{\mathcal{B}(B^+ \rightarrow l^+ \nu_l)_{\text{SM}}} \approx (1 - \tan^2 \beta \frac{m_B^2}{M_H^2})^2.$$

W.S. Hou
Phy.Lett. D 48, 2342

* In a particular MFV scenario with non minimal LFV

$$R_{\mu\tau}^B = \frac{\Gamma(B^+ \rightarrow \mu^+ \nu)}{\Gamma(B^+ \rightarrow \tau^+ \nu)} \quad R_{e\tau}^B = \frac{\Gamma(B^+ \rightarrow e^+ \nu)}{\Gamma(B^+ \rightarrow \tau^+ \nu)}$$

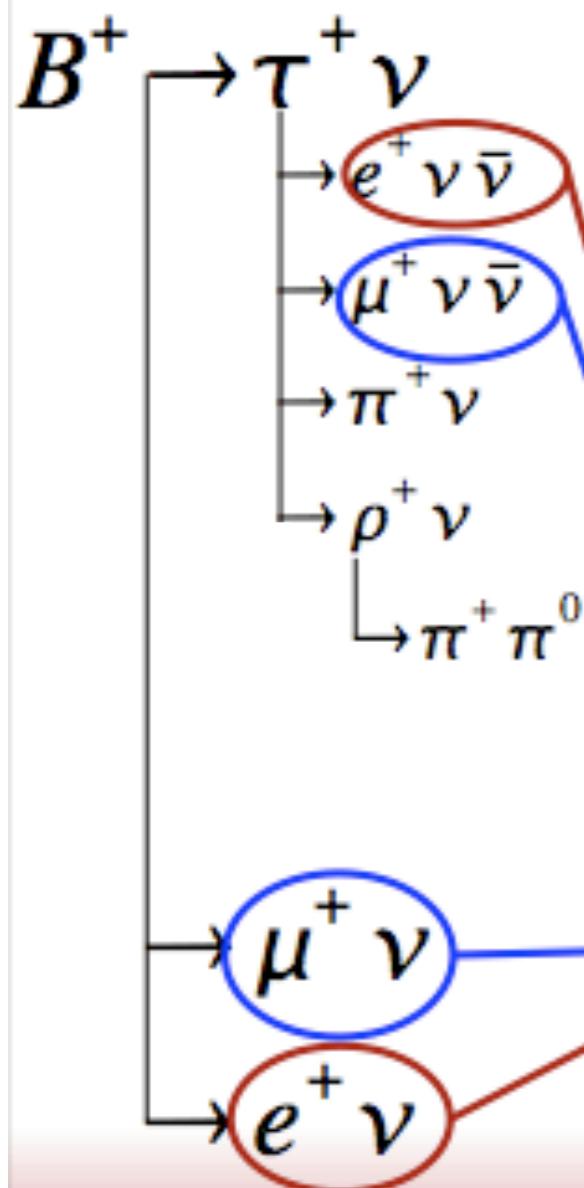
$$\Delta \sim 10\% (R_{\mu\tau}^B)^{\text{SM}} \quad \sim 10^3 \times (R_{e\tau}^B)^{\text{SM}}$$

G.Isidori & P.Paradisi
Phy.Lett. B 639, 499

$B^\pm \rightarrow l^\pm \nu$ with SL recoil

418 fb⁻¹

Tag $B^- \rightarrow \bar{D}^0 \ell^- \bar{\nu}_\ell X$ ($\ell = e$ or μ)



Use p_l^{REST}
for separation

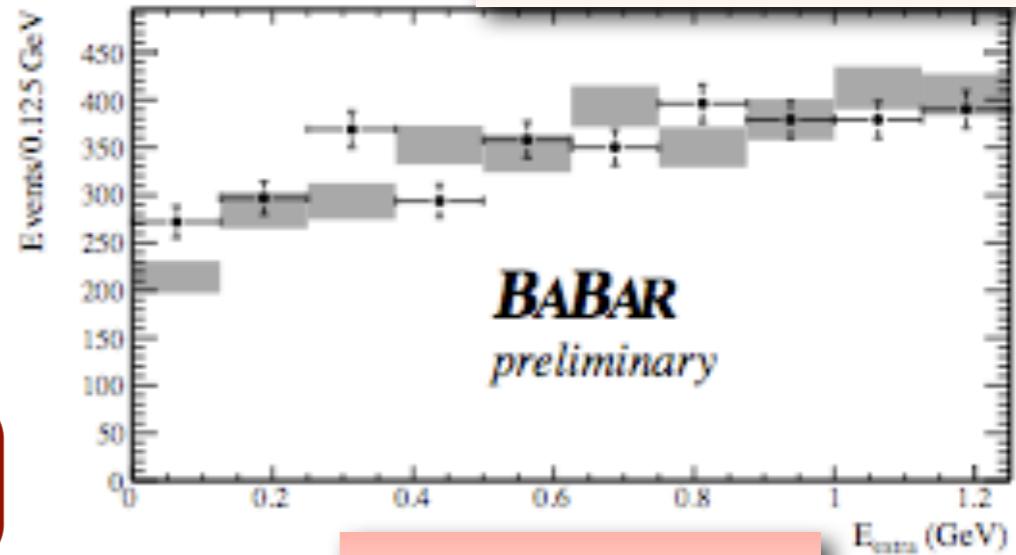
- * Most powerful variables: E_{extra} and momentum of signal lepton in B rest frame (p_l^{REST})
- * Remaining variables considered for likelihood ratios (LHRs) of PDFs separated for continuum and $B\bar{B}$ background
- * Cuts optimized separately for each mode
- * Background estimate from E_{extra} sideband data rescaled with MC



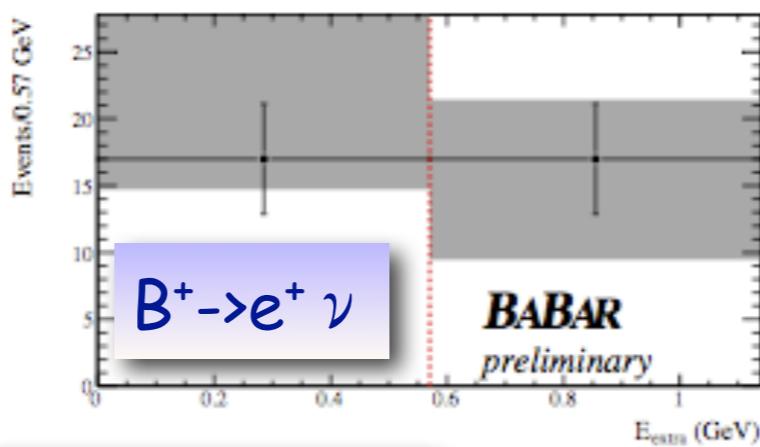
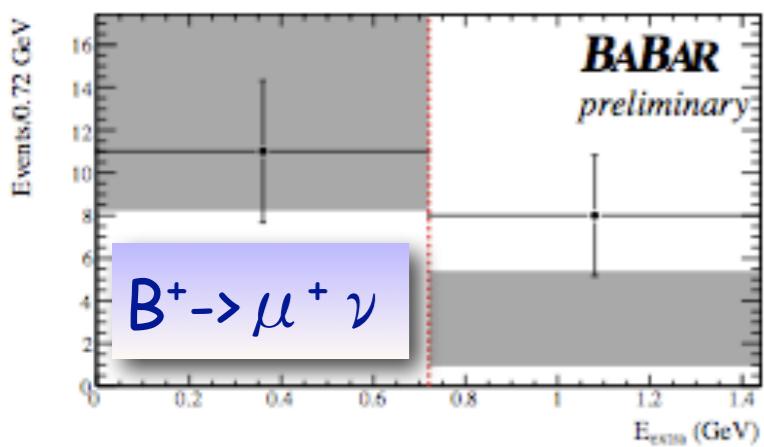
$B^\pm \rightarrow l^\pm \nu$ with SL recoil

arXiv:0809.4027

Mode	Expected Background (N_{BG})	Observed Events (N_{obs})	Overall Efficiency (ε)	Branching Fraction
$\tau^+ \rightarrow e^+ \nu_e \bar{\nu}_\tau$	91 ± 13	148	$(3.08 \pm 0.14) \times 10^{-4}$	$(4.0 \pm 1.2) \times 10^{-4}$
$\tau^+ \rightarrow \mu^+ \nu_\mu \bar{\nu}_\tau$	137 ± 13	148	$(2.28 \pm 0.11) \times 10^{-4}$	$(1.0^{+1.2}_{-0.9}) \times 10^{-4}$
$\tau^+ \rightarrow \pi^+ \bar{\nu}_\tau$	233 ± 19	243	$(3.89 \pm 0.15) \times 10^{-4}$	$(0.6^{+1.1}_{-0.5}) \times 10^{-4}$
$\tau^+ \rightarrow \pi^+ \pi^0 \bar{\nu}_\tau$	59 ± 9	71	$(1.30 \pm 0.07) \times 10^{-4}$	$(2.0^{+1.4}_{-1.3}) \times 10^{-4}$
$B^+ \rightarrow \tau^+ \nu_\tau$	521 ± 31	610	$(10.54 \pm 0.41) \times 10^{-4}$	$(1.8 \pm 0.8 \pm 0.1) \times 10^{-4}$
$B^+ \rightarrow \mu^+ \nu_\mu$	15 ± 10	11	$(27.1 \pm 1.2) \times 10^{-4}$	$< 11 \times 10^{-6}$ @ 90% CL
$B^+ \rightarrow e^+ \nu_e$	24 ± 11	17	$(36.9 \pm 1.5) \times 10^{-4}$	$< 7.7 \times 10^{-6}$ @ 90% CL



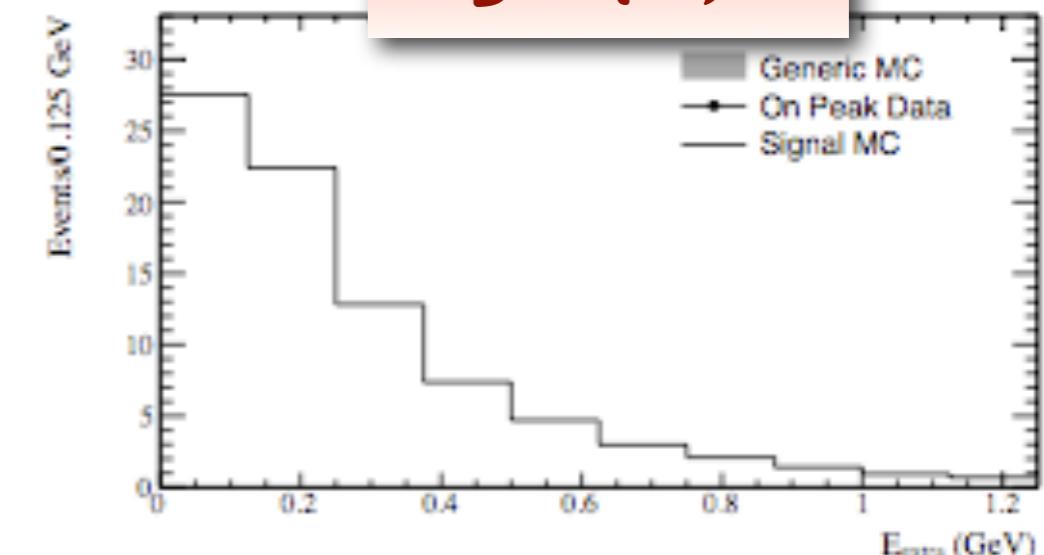
$B^+ \rightarrow \tau^+ \nu$



PRD 77, 011107

Combined with previous BaBar measurement with HAD recoil:

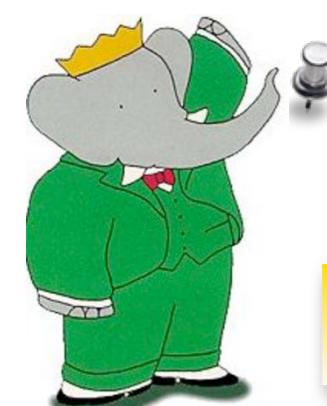
$$B^+ \rightarrow \tau^+ \nu = (1.8 \pm 0.6) \times 10^{-4}$$



Using $|V_{ub}| = (4.43 \pm 0.54) \times 10^{-3}$

$$f_B = 230 \pm 57 \text{ MeV}$$

Latest lattice QCD
 $f_B = 216 \pm 22$
A. Gray et al., PRL 95, 212001



$B^\pm \rightarrow l^\pm \nu$ ($l = e, \mu$) inclusive

253 fb⁻¹

- Look for the highest momentum lepton in the event and use all other tracks and neutral to reconstruct B_{tag}

- Tight requirement on lepton PID and momentum

- Typical background:

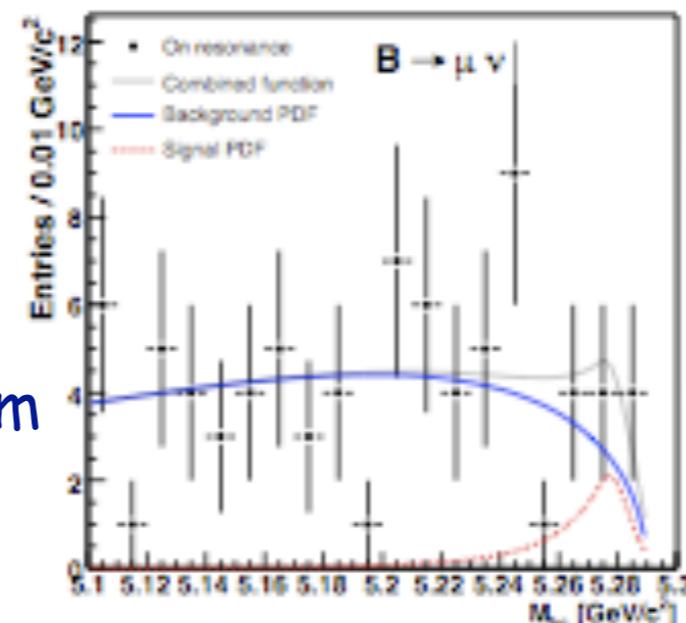
- $qq, B \rightarrow X_u l \nu$

- B_{tag} requirement on ΔE

- Background suppression: modified R_2 in Fisher, $p_T^{\text{miss}} > 1.75$ GeV and $\cos \theta^{\text{miss}} < 0.84$ (0.82)

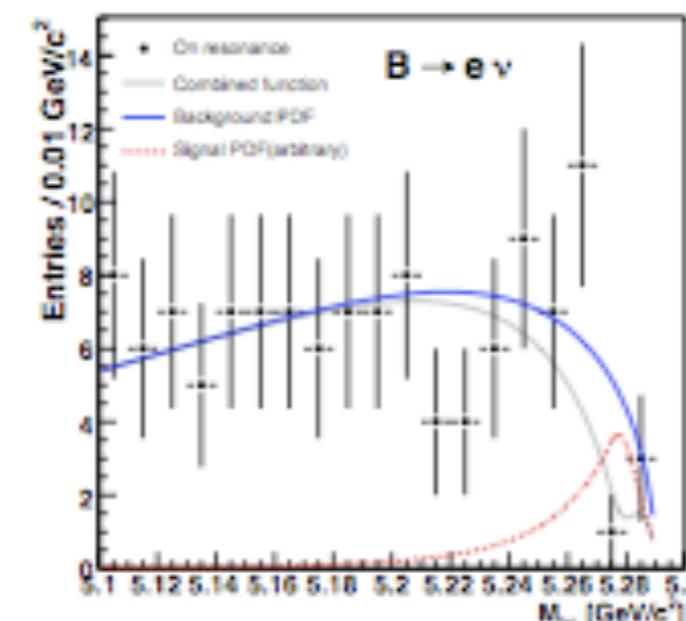
- ML fit to B_{tag} m_{BC}

- UL extraction integrating 90% of likelihood



$B^+ \rightarrow \mu^+ \nu$

Efficiency $(2.2 \pm 0.1)\%$
Yield 4.1 ± 3.1



$B^+ \rightarrow e^+ \nu$

Efficiency $(2.4 \pm 0.1)\%$
Yield -1.8 ± 3.3

$$B^\pm \rightarrow \mu^\pm \nu < 1.7 \times 10^{-6}$$

$$B^\pm \rightarrow e^\pm \nu < 9.8 \times 10^{-7}$$

Phys.Lett. B 647, 67

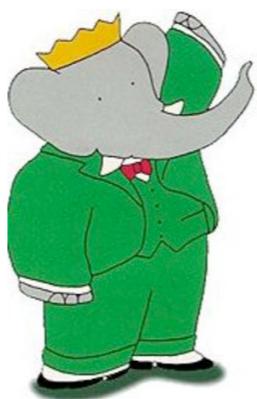


$B^\pm \rightarrow l^\pm \nu$ ($l = e, \mu$) inclusive

426 fb⁻¹

Reconstruction technique similar to Belle's

Additional background from two photon processes for electron mode



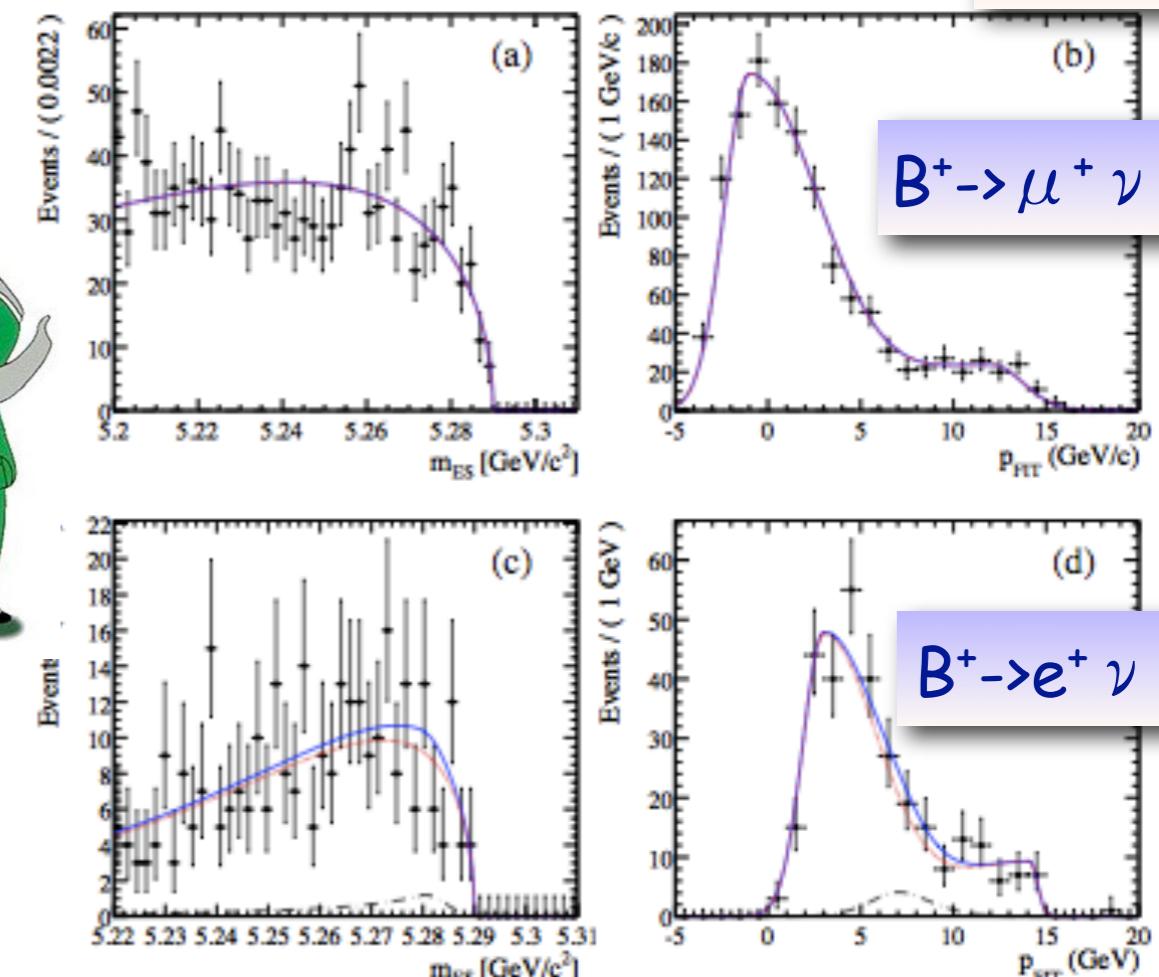
B_{tag} requirement on ΔE (and p_T)

Background suppression: topological and kinematical Fisher optimized separately for each mode on 5 different variables

ML fit to B_{tag} m_{ES} and linear combination of signal lepton momentum in B rest frame and c.m. frame

arXiv:0903.1220
Preliminary, submitted to Phys.Rev. D

UL extraction in Bayesian approach



$B^+ \rightarrow \mu^+ \nu$
Efficiency $(6.1 \pm 0.2)\%$
Yield 1.4 ± 17.2

$B^+ \rightarrow e^+ \nu$
Efficiency $(4.7 \pm 0.3)\%$
Yield 17.9 ± 17.6

$B^\pm \rightarrow \mu^\pm \nu < 1.0 \times 10^{-6}$
 $B^\pm \rightarrow e^\pm \nu < 1.9 \times 10^{-6}$

$B^\pm \rightarrow \mu^\pm \nu$ constraint

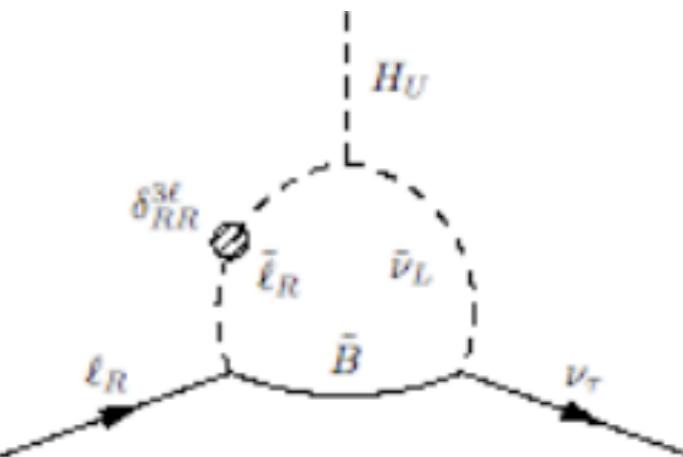
$M = \pi, K, D, B\dots$

$$R_M^{j/k} = \frac{\sum_i \Gamma(M \rightarrow l_j \nu_i)}{\sum_i \Gamma(M \rightarrow l_k \nu_i)} \quad i, j, k = e, \mu, \tau.$$

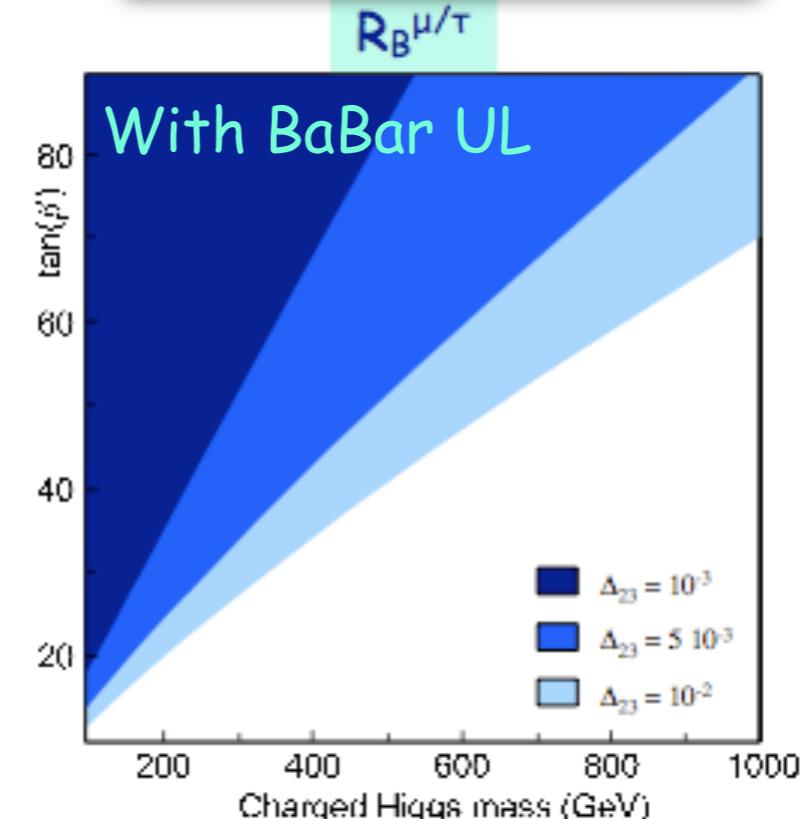
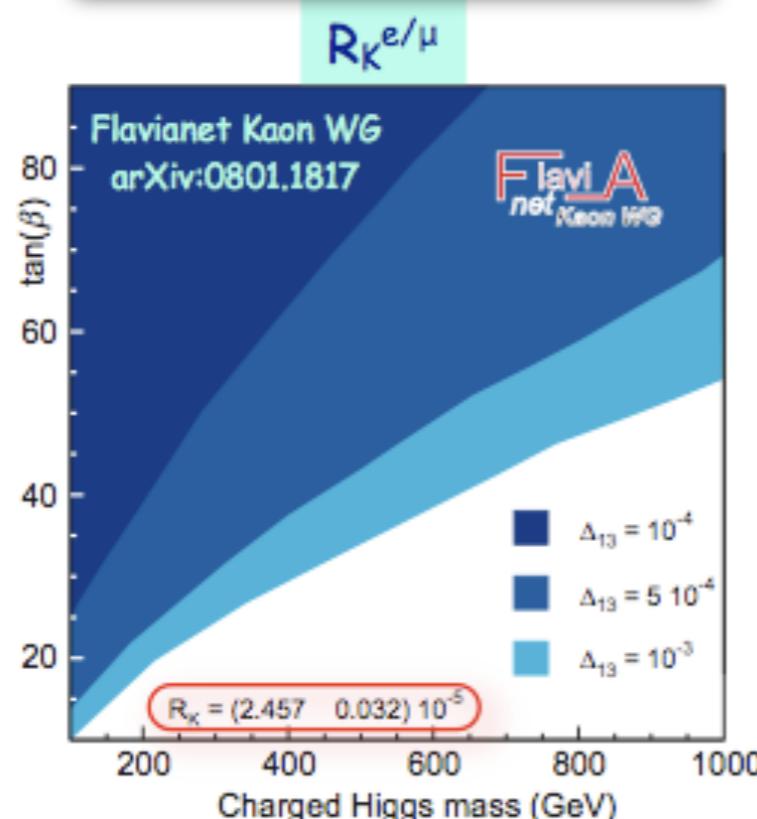
$$(R_M^{j/k})_{\text{LFV}}^{\text{MSSM}} = (R_M^{j/k})^{\text{SM}} \left[1 + \frac{1}{R_{Mk\nu}} \left(\frac{m_M^4}{M_{H^\pm}^4} \right) \left(\frac{m_k^2}{m_j^2} \right) |\Delta_R^{\tau j}|^2 \frac{\tan^6 \beta}{(1 + \epsilon \tan \beta)^2} \right]$$

With K decays, tau not accessible so only Δ_{13}
 R_K measured at $O(1\%)$ accuracy

With B decays,
 Δ_{13} AND Δ_{23}
Only UL on R_B but similar constraint!!!!



Isidori & Paradisi
Phys.Lett. B 639, 499



B⁻ → J/ψ ϕ

$B^0 \rightarrow J/\psi \phi < 9.2 \times 10^{-6}$

BaBar, Phys.Rev.Lett.
91, 071801

Probe for rescattering effect

- Important to understand patterns of CP asymmetries for charmless 2-body B decays

Selection cuts:

$$-150 \text{ } (-60) \text{ MeV}/c^2 < M_{e^+e^-(\gamma)}(M_{\mu^+\mu^-}) - m_{J/\psi} < +36 \text{ } (+36) \text{ MeV}/c^2$$

$$|m_{K^+K^-} - m_\phi| < 10 \text{ MeV}/c^2$$

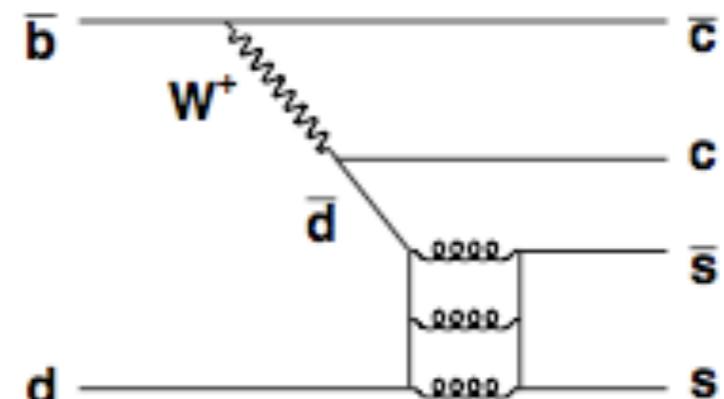
$$5.27 \text{ GeV}/c^2 < M_{bc} < 5.29 \text{ GeV}/c^2$$

Dominant backgrounds (taken into account in the ML fit):

$$B^0 \rightarrow J/\psi K^{*0}(892)[\rightarrow K^-\pi^+] \quad \cdots \cdots$$

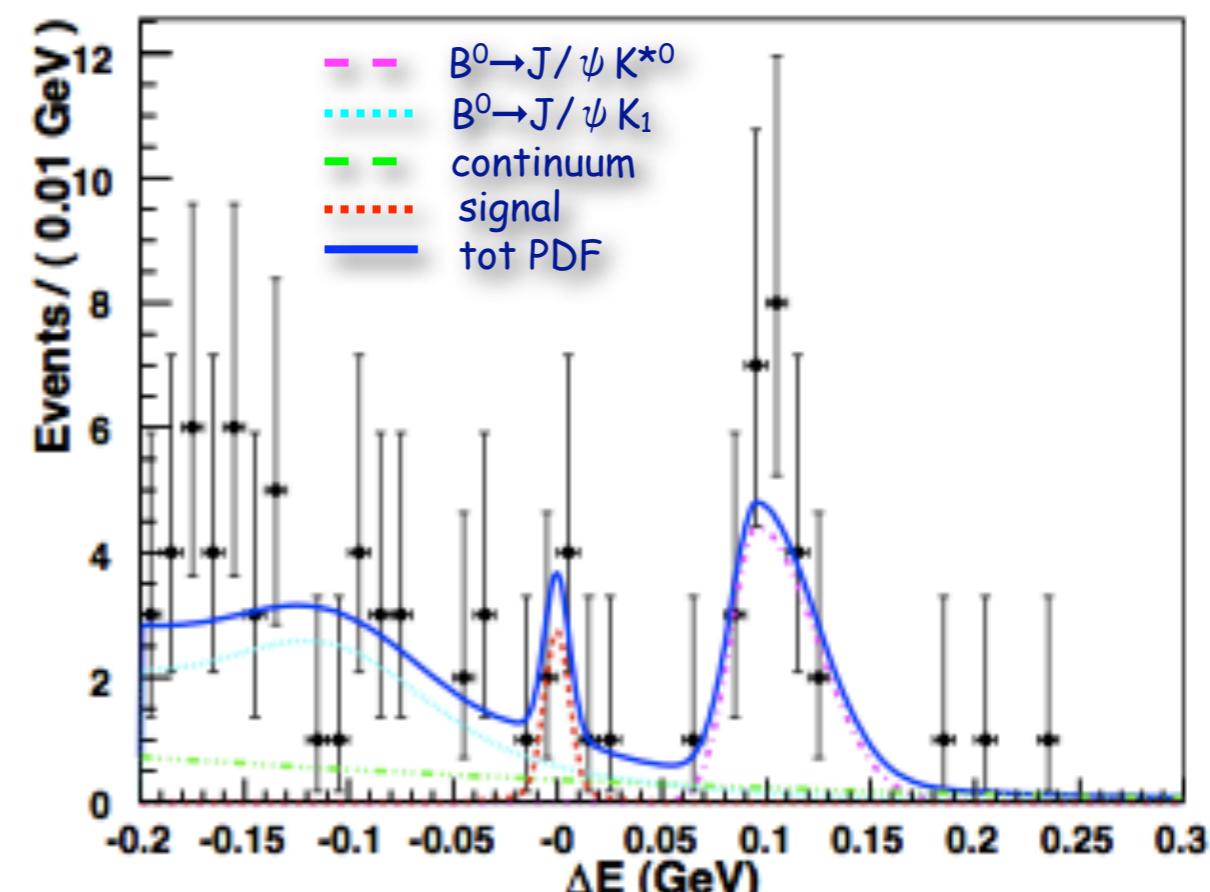
$$B^{0/-} \rightarrow J/\psi K_1(1270)[\rightarrow K^-\pi^+\pi^{0/-}] \quad \cdots \cdots$$

Signal yield	$4.6^{+3.1}_{-2.5}$
Significance	2.3σ
Upper limit of signal yield (Y_{90})	9.5
Detection efficiency (ϵ)	26.2%
Upper limit of branching fraction	$< 9.4 \times 10^{-7}$



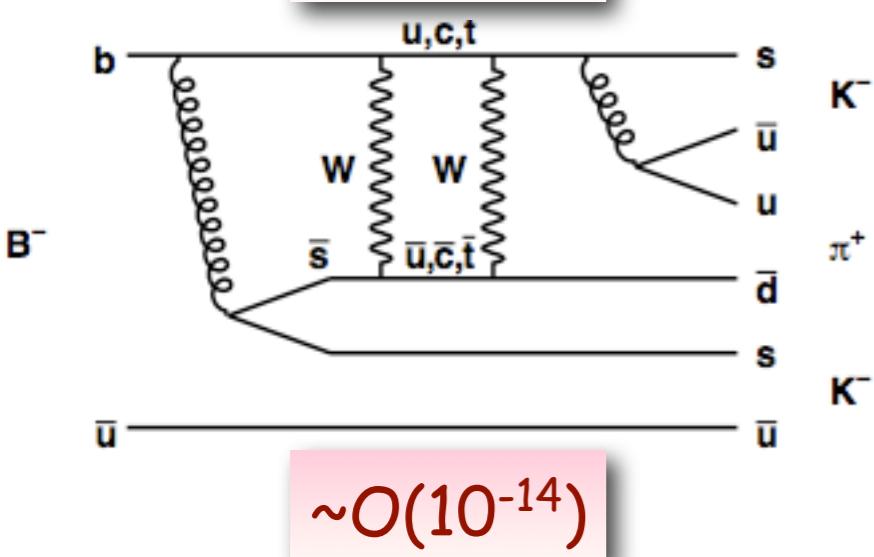
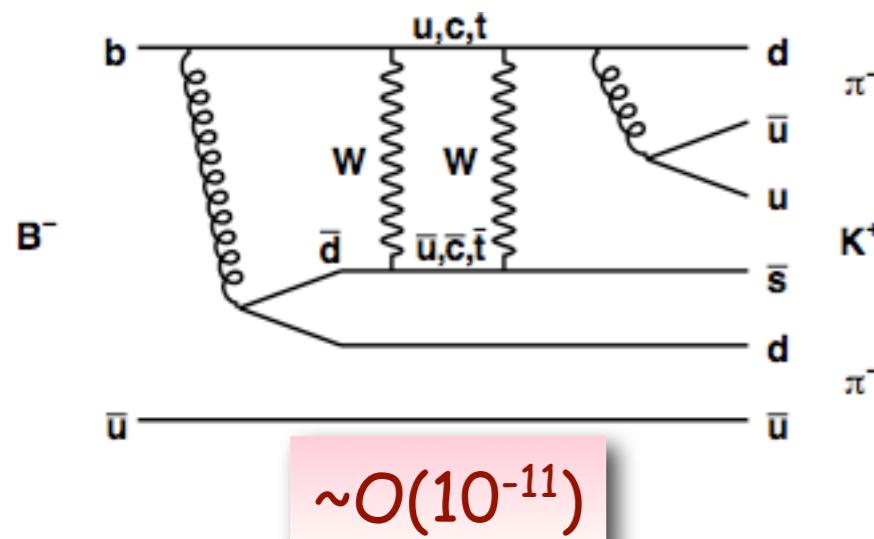
Phys.Rev.D 78 011106

605 fb⁻¹



$B^+ \rightarrow K^- \pi^+ \pi^- / K^- K^+ \pi^-$

$b \rightarrow q\bar{q}s/b \rightarrow q\bar{q}d \simeq (V_{td}V_{ts}^* \sim \lambda^5 \simeq 3 \cdot 10^{-5}) \cdot b \rightarrow q\bar{q}s/b \rightarrow q\bar{q}d$



$$\mathcal{H}_{\text{eff.}} = \sum_{n=1}^{\infty} [C_n \mathcal{O}_n + \tilde{C}_n \tilde{\mathcal{O}}_n],$$

$$\mathcal{O}_1 = \bar{d}_L^i \gamma^\mu b_L^i \bar{d}_R^j \gamma_\mu s_R^j,$$

$$\mathcal{O}_2 = \bar{d}_L^i \gamma^\mu b_L^j \bar{d}_R^j \gamma_\mu s_R^i,$$

$$\mathcal{O}_3 = \bar{d}_L^i \gamma^\mu b_L^i \bar{d}_L^j \gamma_\mu s_L^j,$$

$$\mathcal{O}_4 = \bar{d}_R^i b_L^i d_L^j s_R^j,$$

$$\mathcal{O}_5 = \bar{d}_R^i b_L^j \bar{d}_L^j s_R^i,$$

Z'

SM

MSSM

RPV

$$\Gamma_{\pi\pi K}^{(MS)SM} = |C_3^{(MS)SM}|^2 \times 2.0 \times 10^{-3} \text{ GeV}^5,$$

$$\Gamma_{\pi\pi K}^{RPV} = |C_4^{RPV} + \tilde{C}_4^{RPV}|^2 \times 9.2 \times 10^{-3} \text{ GeV}^5,$$

$$\Gamma_{\pi\pi K}^{Z'} = |C_1^{Z'} + \tilde{C}_1^{Z'}|^2 \times 1.0 \times 10^{-2} \text{ GeV}^5$$

$$+ |C_3^{Z'} + \tilde{C}_3^{Z'}|^2 \times 1.3 \times 10^{-3} \text{ GeV}^5$$

$$+ \text{Re} [(C_1^{Z'} + \tilde{C}_1^{Z'}) (C_3^{Z'} + \tilde{C}_3^{Z'})^*] \\ \times 6.7 \times 10^{-3} \text{ GeV}^5.$$

Can constrain RPV :

$$\left| \sum_{n=1}^3 \left(\frac{100 \text{ GeV}}{m_{\tilde{\nu}_n}} \right)^2 \lambda'_{n21} \lambda'^*_{n13} \right| < 8.9 \times 10^{-5},$$

$B^+ \rightarrow K^- \pi^+ \pi^- / K^- K^+ \pi^-$ analysis

$B^- \rightarrow K^+ \pi^- \pi^+ < 1.8 \times 10^{-6}$
 $B^- \rightarrow K^+ K^- \pi^+ < 1.3 \times 10^{-6}$

BaBar, Phys.Rev.Lett.
91, 051801 (2003)

Phys.Rev.D 78
091102

426 fb^{-1}

J/ ψ , D⁰ and $\psi(2S)$ vetos

Efficiencies: 21.6% / 17.8%

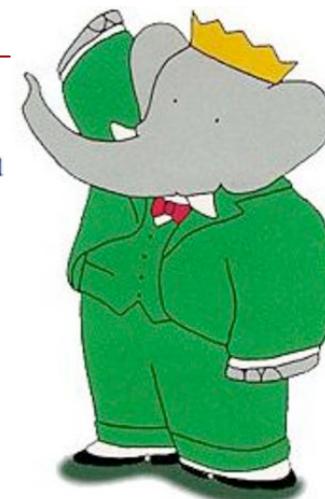
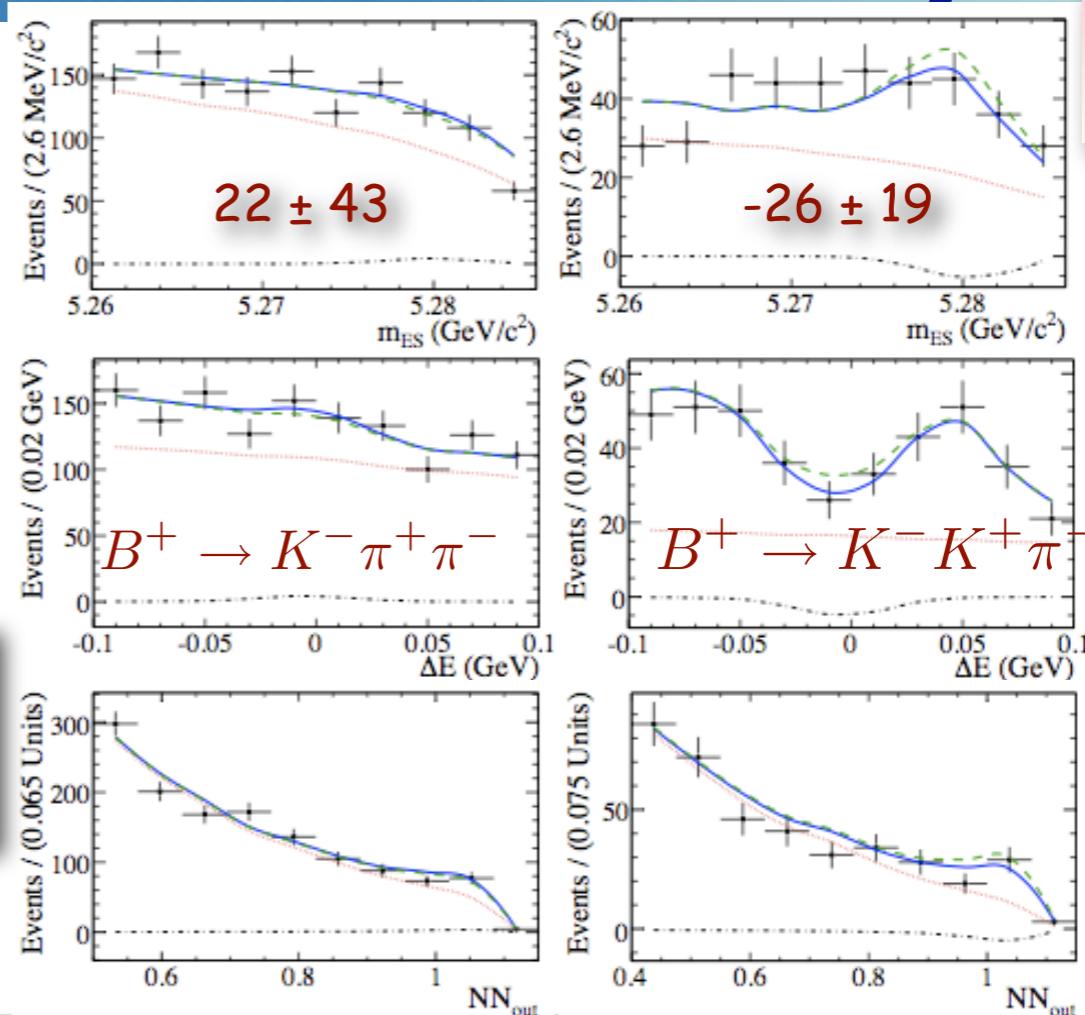
NN variables: $L_2/L_0, |\cos \theta_{\text{beam}}|, |\cos \theta_{\text{thrust}}|,$
 B_{tag} flavour, $\Delta t/\sigma_{\Delta t}$

Four specific bkg categories +
BB generic + continuum

Feldman-Cousins UL @ 90%:

$B^\pm \rightarrow K^\mp \pi^+ \pi^- < 7.4 \times 10^{-7}$

$B^\pm \rightarrow K^+ K^- \pi^\mp < 4.2 \times 10^{-7}$



$B^- \rightarrow K^+ \pi^- \pi^-$				
Category	1	2	3	
Dominant mode(s)	$B^- \rightarrow D^0 \pi^-; D^0 \rightarrow K^- K^+$	$B^- \rightarrow \pi^- \pi^+ \pi^-$	$B^- \rightarrow K^- \pi^+ \pi^- \& B^0 \rightarrow K^+ \pi^- \pi^0$	$B^0 \rightarrow K^+ \pi^-$
Number of expected events	80 ± 3	57 ± 4	472 ± 24	43 ± 1
Number of observed events	61 ± 70	-153 ± 94	1116 ± 347	-26 ± 152
m_{ES} Structure	Peaking	Peaking	Broad peak	Broad peak
ΔE Structure	Left peak	Right peak	Broad peak	Right peak
$B^- \rightarrow K^- K^- \pi^+$				
Category	1	2	3	
Dominant mode(s)	$B^- \rightarrow K^- K^+ K^-$	$B^- \rightarrow K^- \pi^+ \pi^-$	$B^- \rightarrow D^0 \pi^-; D^0 \rightarrow K^- \pi^+ \pi^0$	Generic $B^+ B^-$
Number of expected events	190 ± 9	198 ± 9	61 ± 4	312 ± 11
Number of observed events	213 ± 41	240 ± 37	-34 ± 55	380 ± 117
m_{ES} Structure	Peaking	Peaking	Broad peak	Broad peak
ΔE Structure	Left peak	Right peak	Left peak	Continuum-like

Conclusion & Outlook

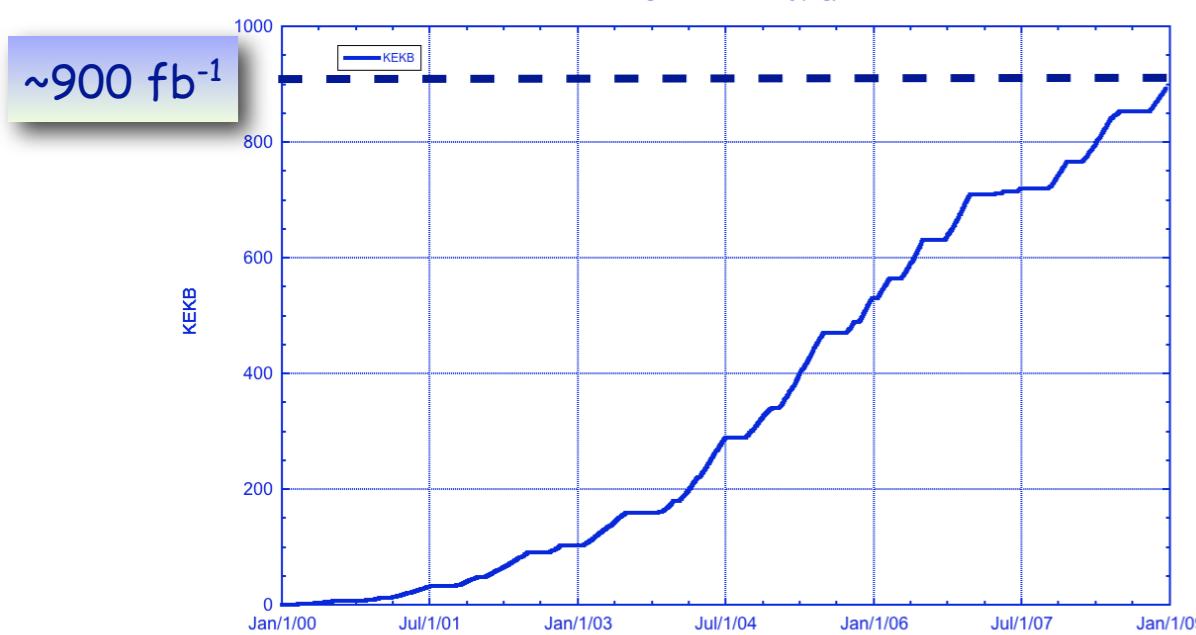
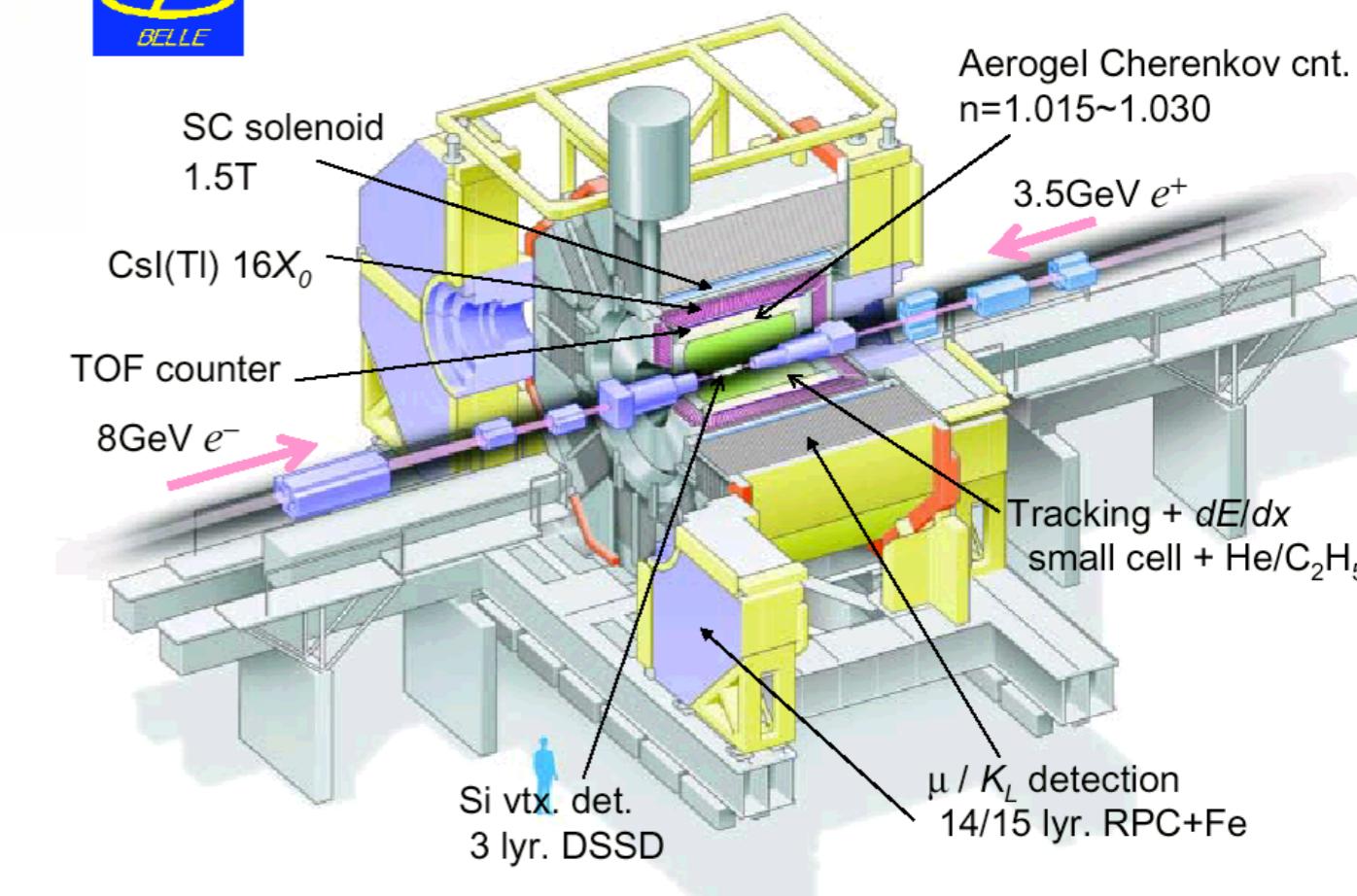
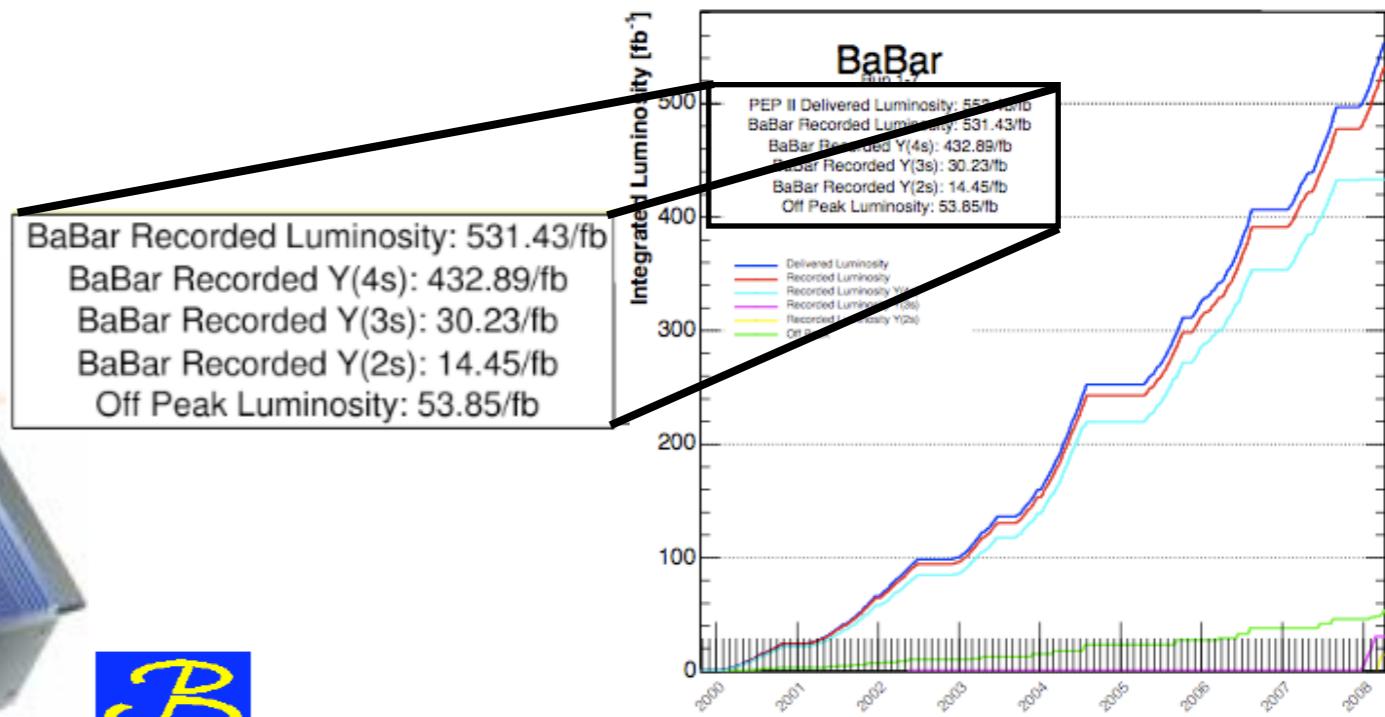
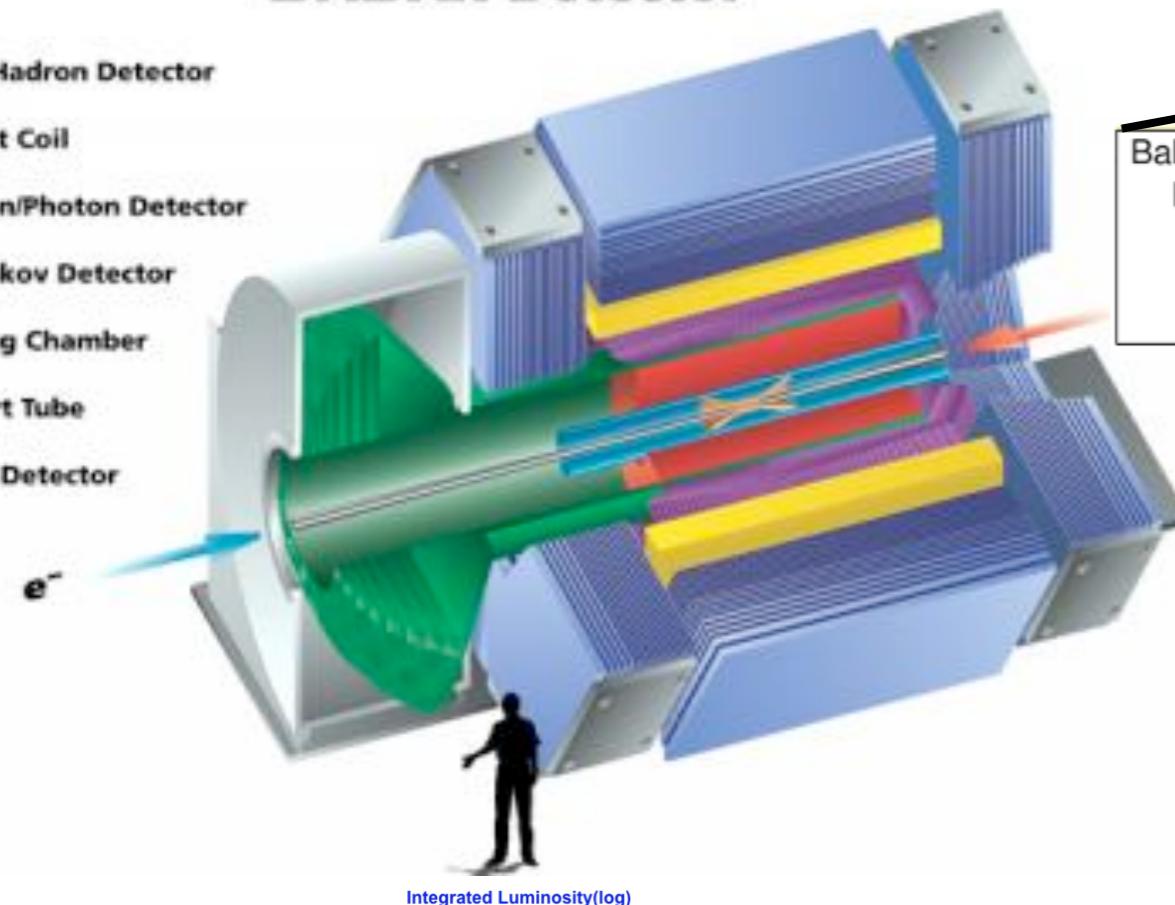
- Rare decays are standard probes for NP searches given the low decay rates
- They are complementary to the direct exploration of energy frontier and can access even higher scales
- Thanks to the improved analysis techniques and the huge integrated luminosity, today is possible to reach $O(10^{-6}-10^{-7})$ in sensitivity
- Even if only UL, rare decays are already able to impose interesting constraints on various NP scenarios
- Nonetheless, decays with undetectable particles in the final state will not be measurable at the LHC and a Super Flavour Factory will be needed in order to obtain improved measurements

Backup Slides

Detectors & Datasets

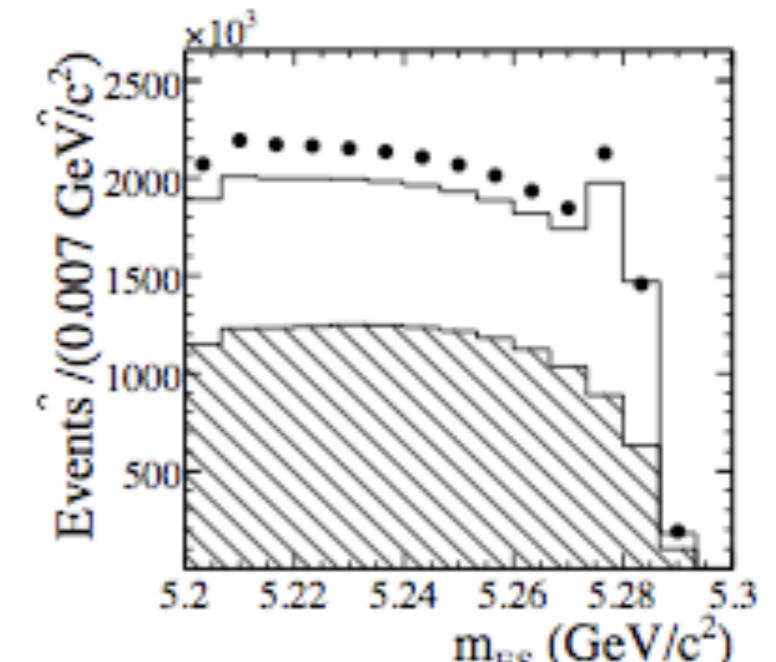
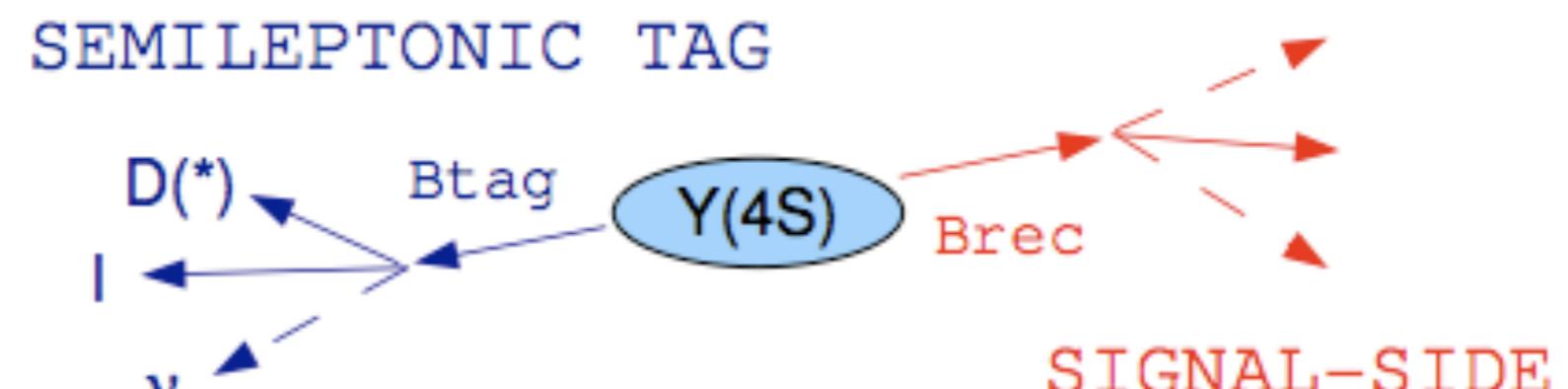
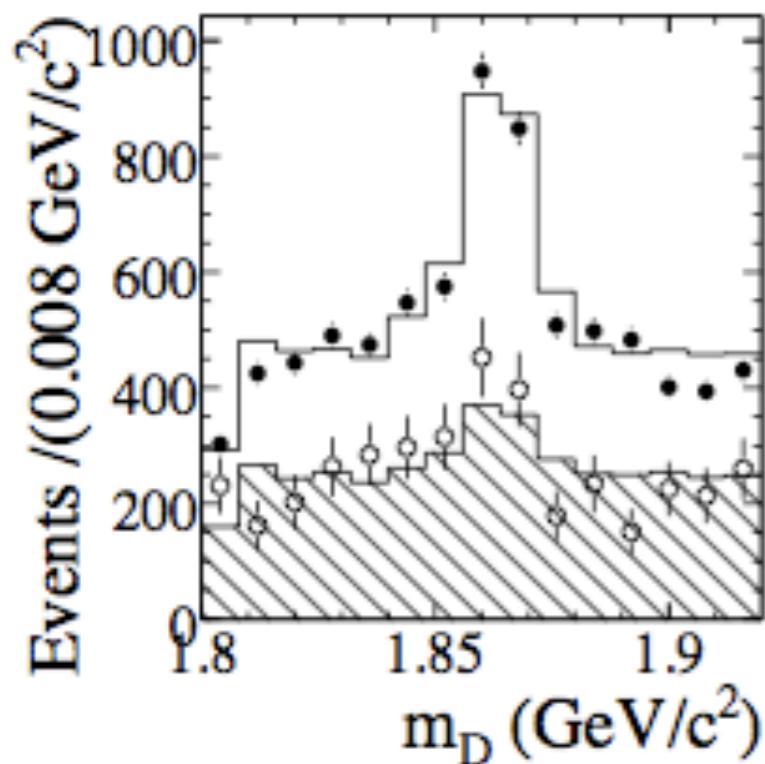
BABAR Detector

- Muon/Hadron Detector
- Magnet Coil
- Electron/Photon Detector
- Cherenkov Detector
- Tracking Chamber
- Support Tube
- Vertex Detector



Recoil Technique

Powerful technique providing a pure and clean B sample
which you pay with a low efficiency $\sim O(0.01) - O(0.001)$



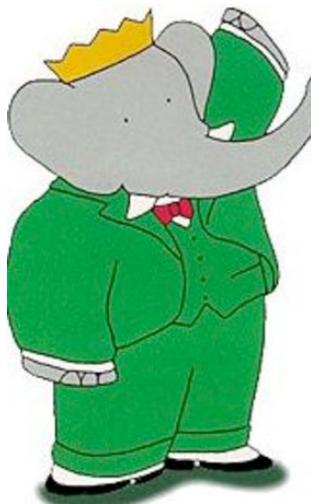
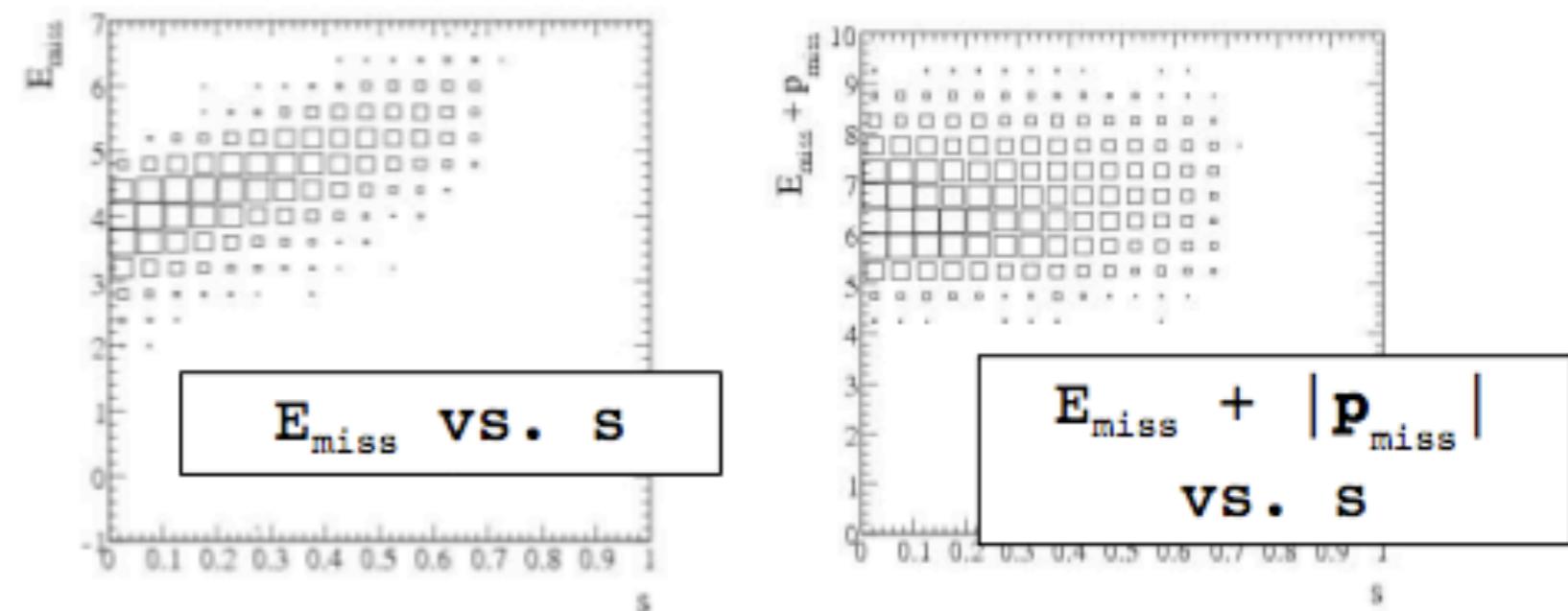
$$m_{ES} = \sqrt{s/4 - \vec{p}_B^2}$$

$B \rightarrow K^* \nu \bar{\nu}$ Model Un-dependence

*Selection and Fit Variables chosen in order to minimize
the dependence on the kinematical model
(i.e. use variables with NO correlation to $s = m_{\nu\nu}^2/m_B^2$)*

missing 4-momentum:

$$\mathbf{p}_{\text{miss}} = \mathbf{p}_{\text{beams}} - \mathbf{p}_{\text{DI}} - \mathbf{p}_{K^*}$$



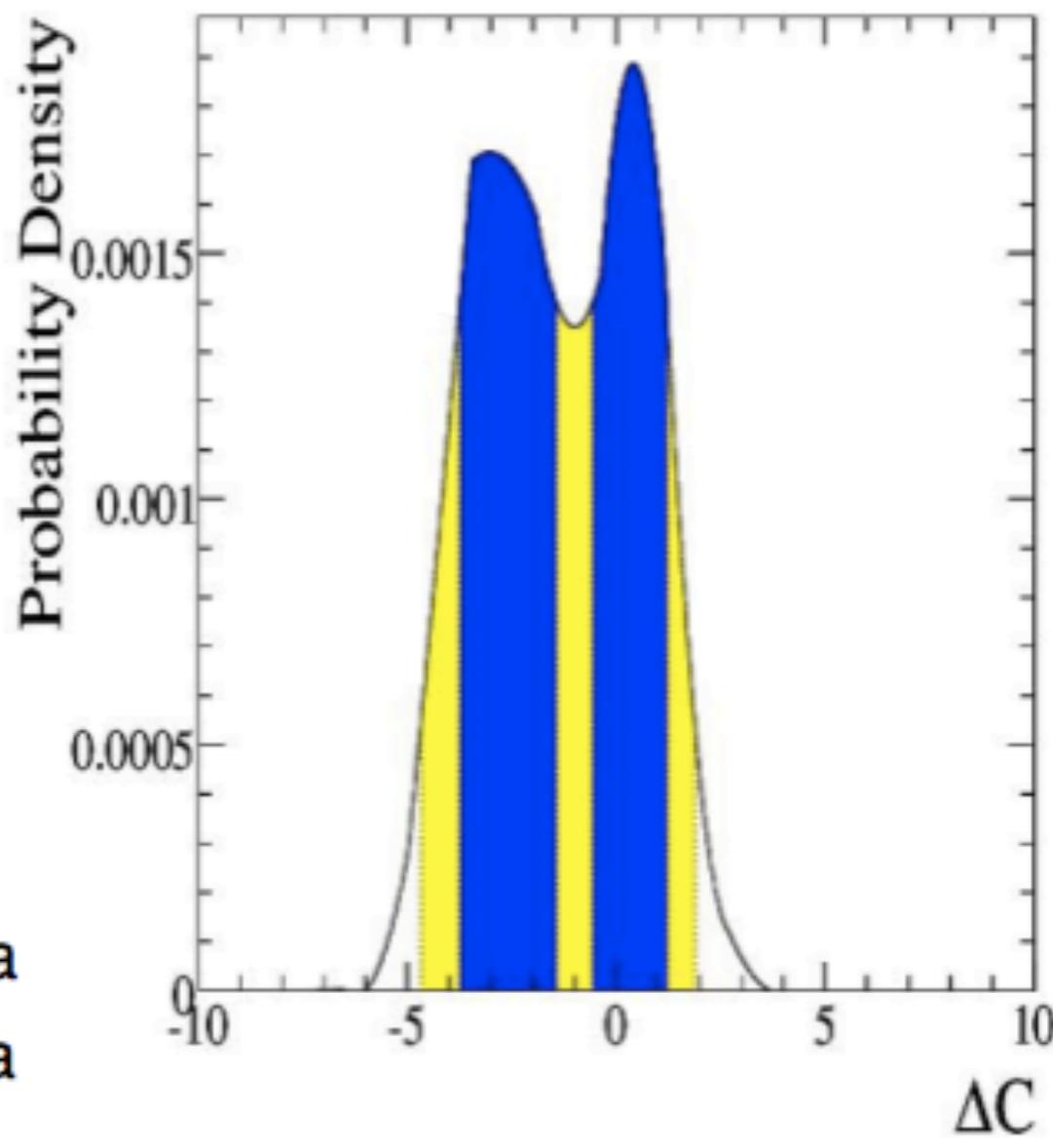
$B \rightarrow K^* \nu \bar{\nu}$ and MFV SUSY

- Assume a Minimal Flavor Violation (MFV) scenario:
 - NP enters only through modifications of the functions $B(x_t)$ and $C(x_t)$;
- NP in $B(x_t)$ expected to give small contributions;
- Set a limit on $\Delta C = C - C_{SM}$ assuming $B = B_{SM}$.

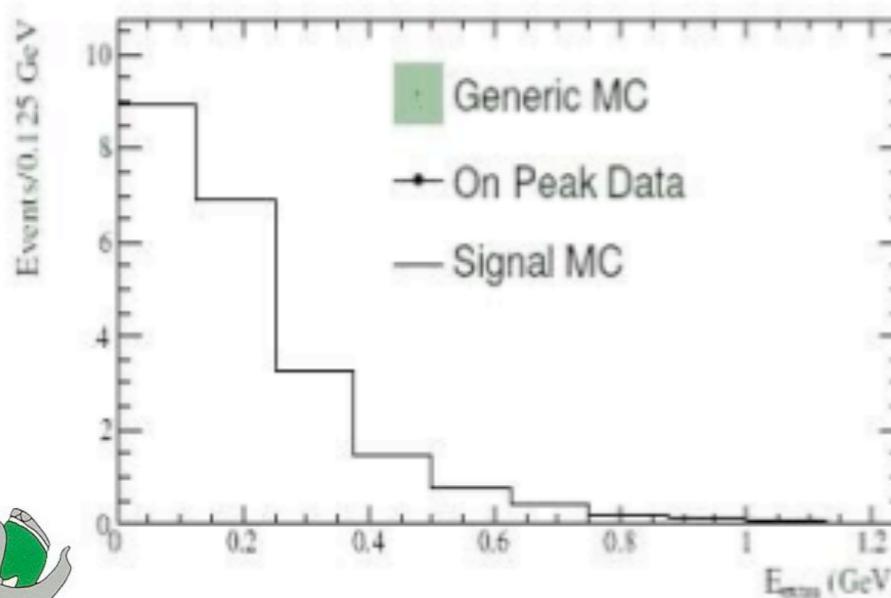
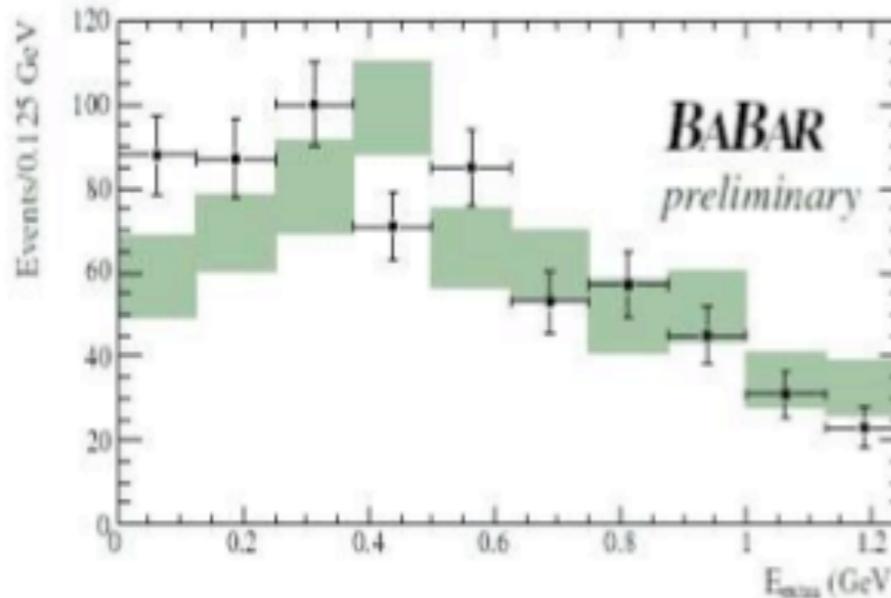
All the most recent results for
 $B \rightarrow K^* \nu \bar{\nu}$ are used

NP in C as large as 6 times the SM can be excluded at 95% C.L.

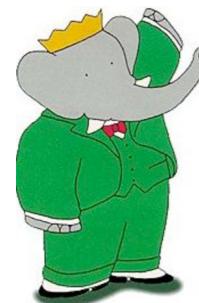
- 68% prob. area
- 95% prob. area



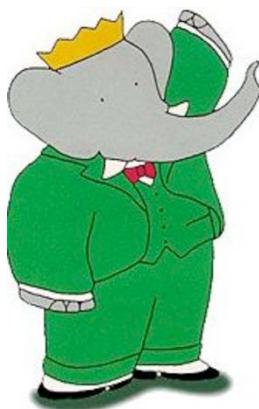
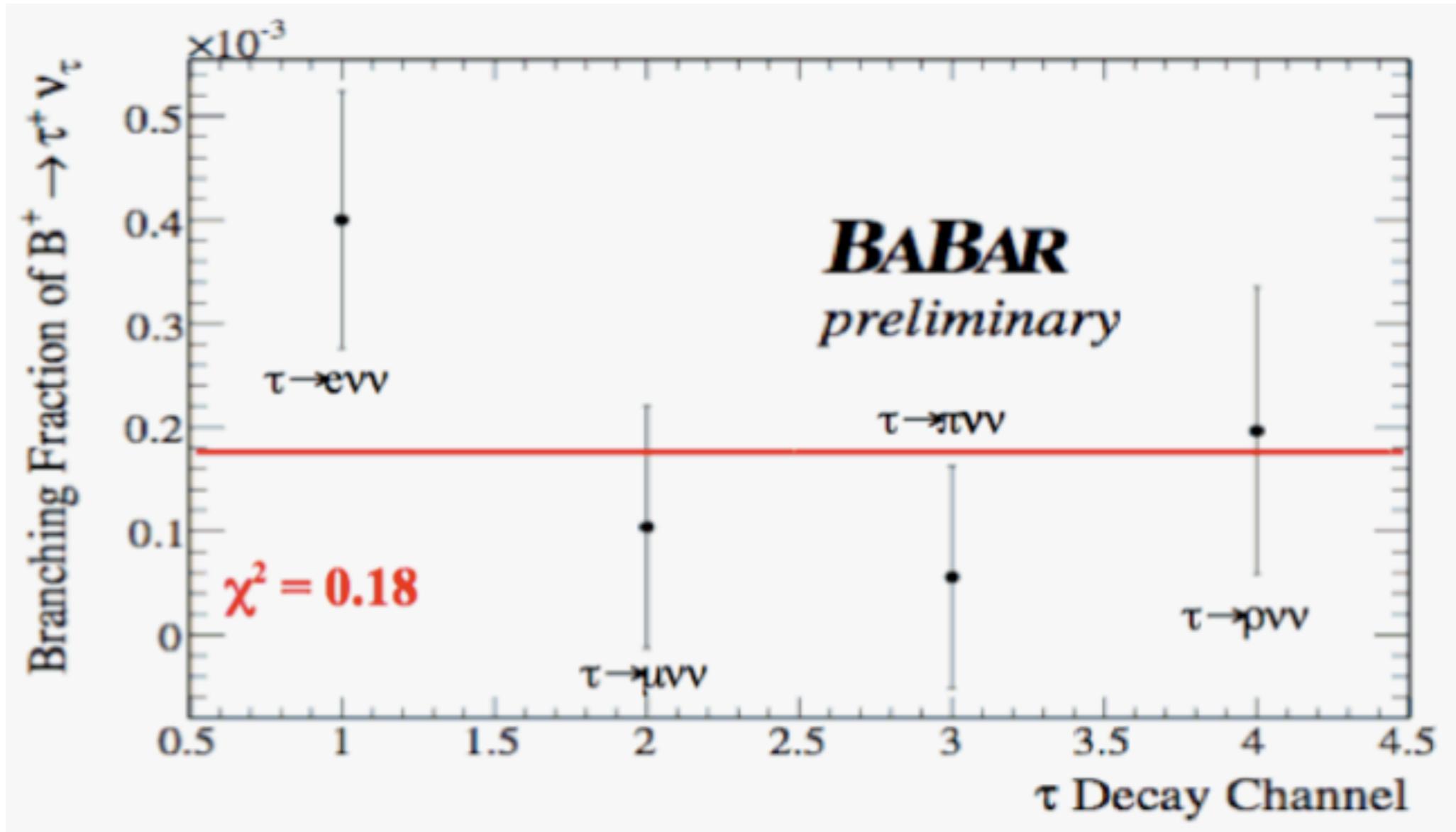
$B^\pm \rightarrow l^\pm \nu$ with SL recoil



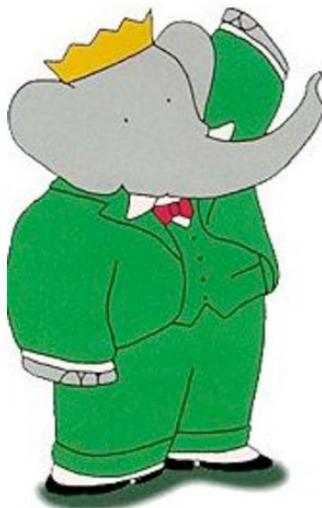
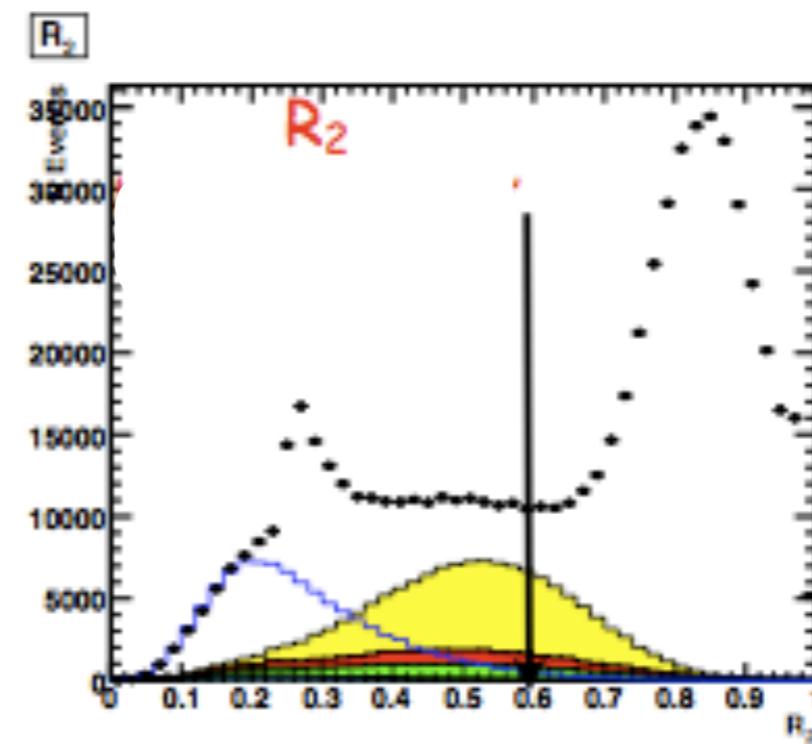
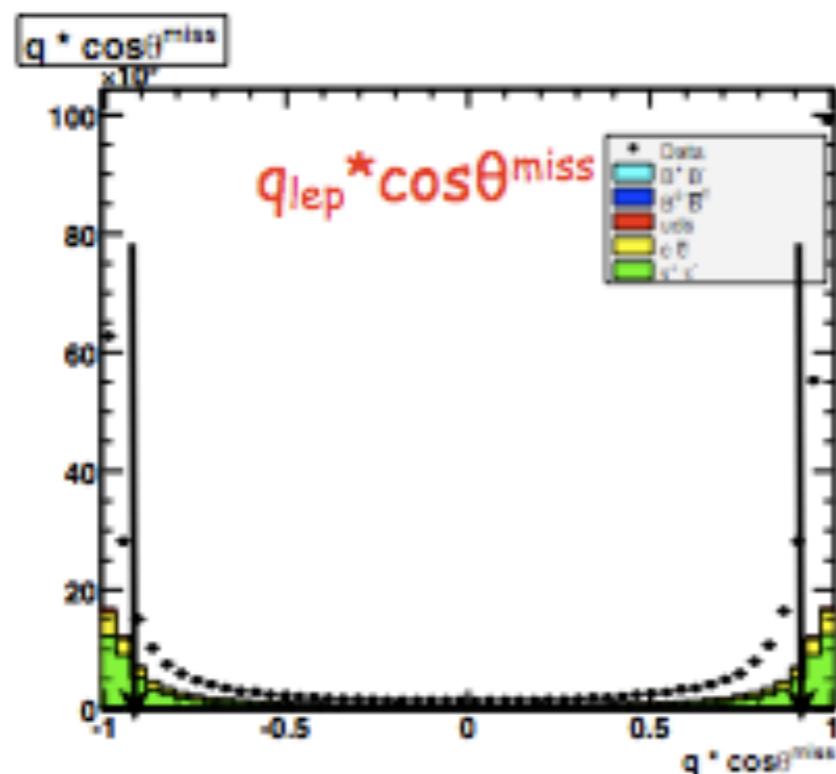
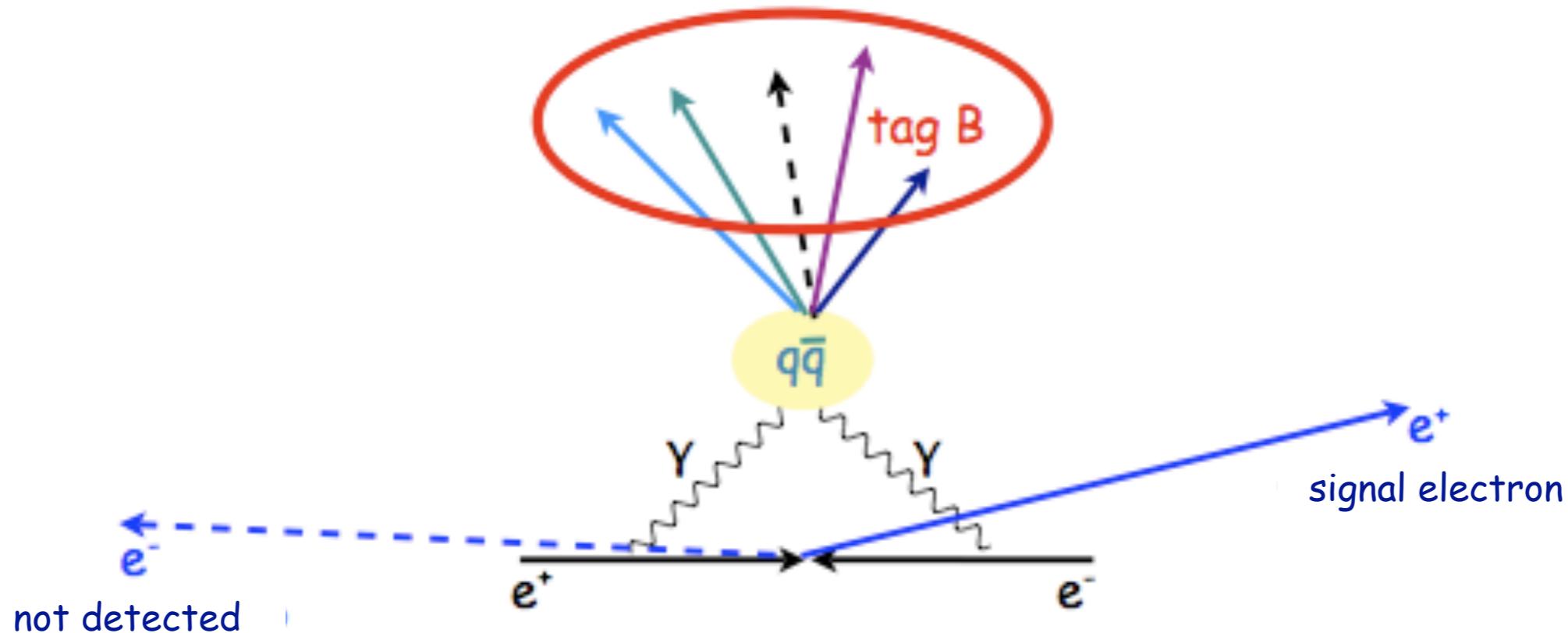
- Large excess in first 3 bins gives:
 $\text{BF}(B \rightarrow \tau\nu(\tau \rightarrow e\nu\nu)) = (4.0 \pm 1.2) \times 10^{-4}$
- Many sideband/control sample studies performed:
 - two photon fusion QED events: where a fake D0 is reconstructed and the e^+, e^- are reconstructed as the tag or signal leptons. No excess seen in the D0 sidebands.
 - events that contain overlapping e^+e^- collisions: study the separation of the reconstructed B vertices, Δz : possible excess at high Δz , however no excess found.
 - other samples studied include photon pair production and Bremsstrahlung recovered electrons
 - Same number of electrons, muons from the tag B: expected for true signal



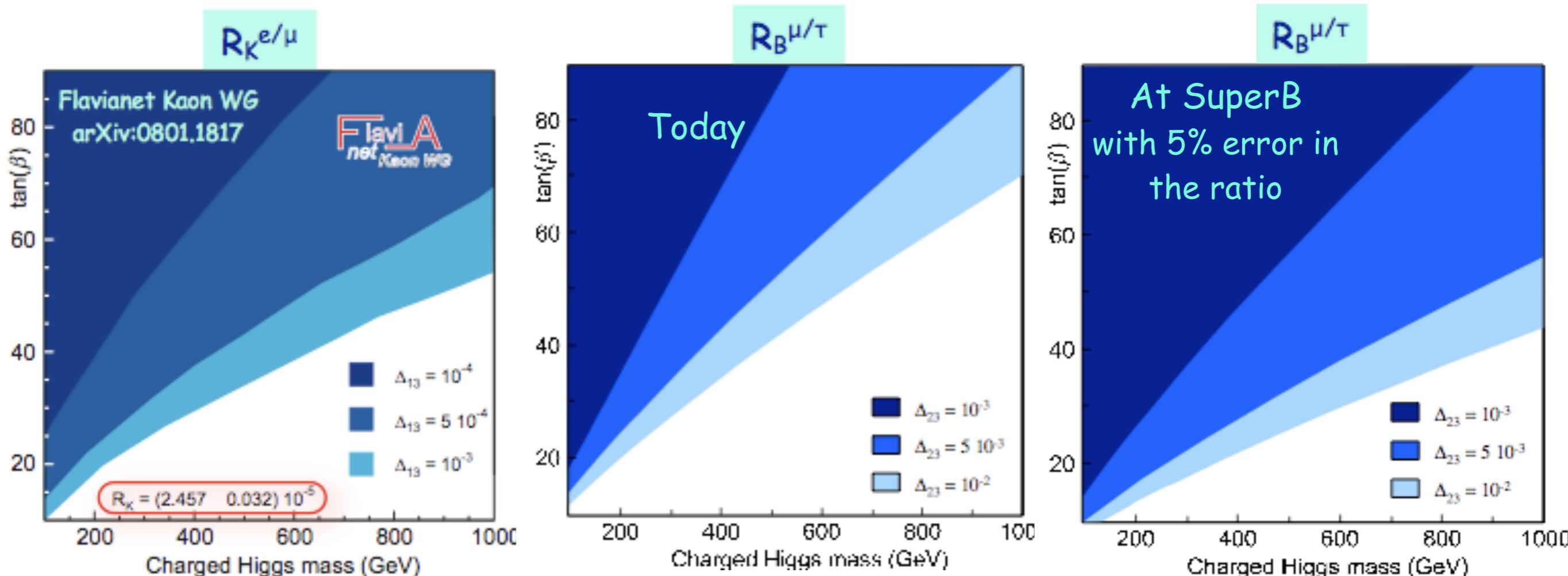
$B^\pm \rightarrow l^\pm \nu$ with SL recoil



Photon Fusion Event



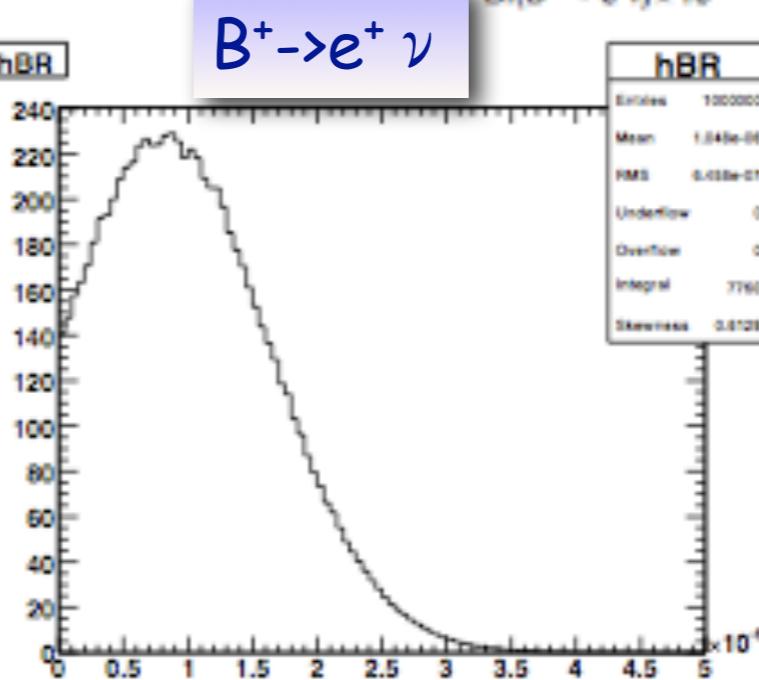
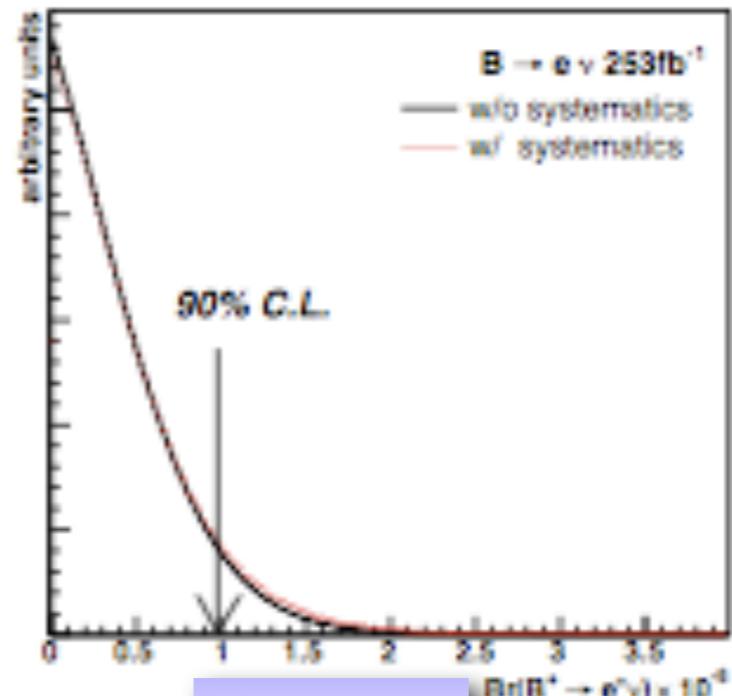
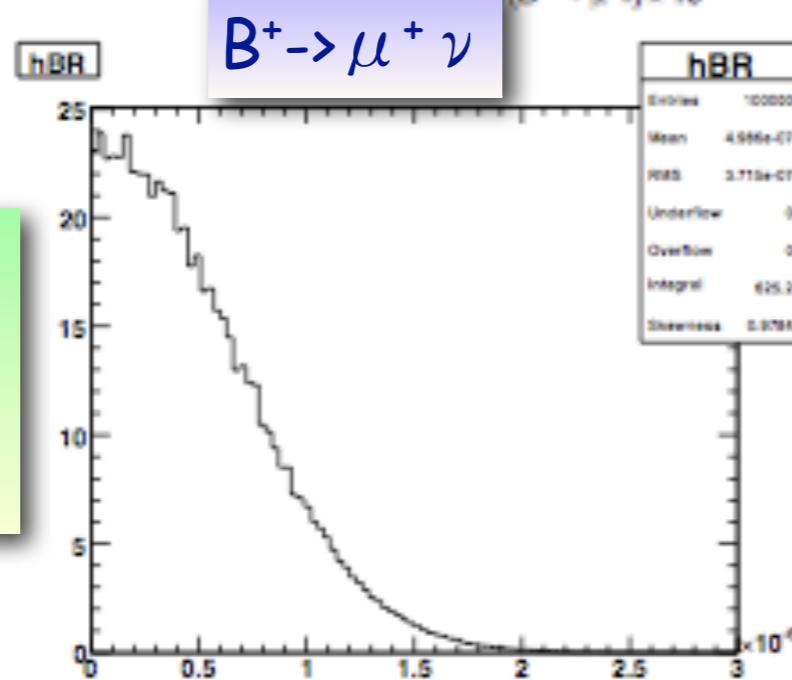
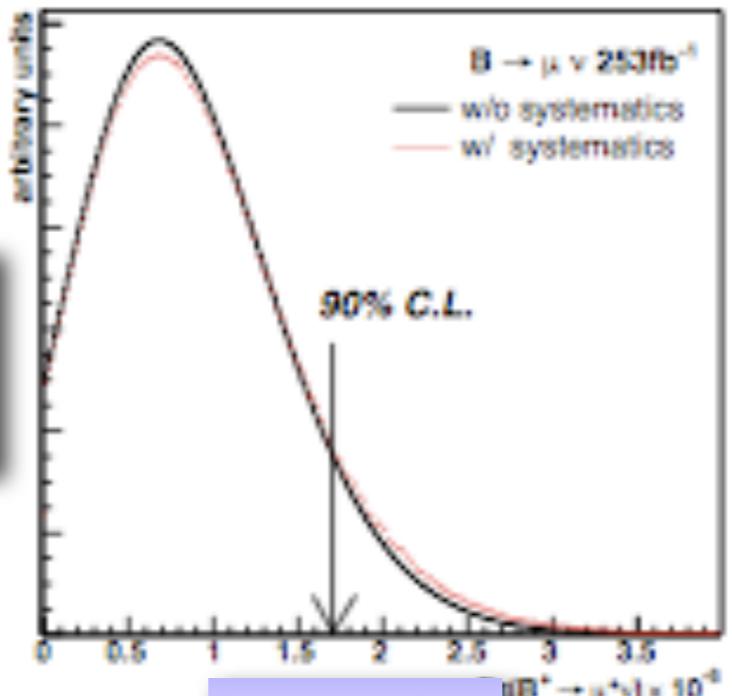
$B^\pm \rightarrow \mu^\pm \nu$ constraint



$B^\pm \rightarrow l^\pm \nu$ ($l=e, \mu$) inclusive

BR Likelihoods

BR Likelihood
from N_{observed}



Bayesian
Posterior BR
Likelihood

