Search for massive invisible particle X^0 in $B^+ \rightarrow e^+ X^0$ and $B^+ \rightarrow \mu^+ X^0$ decays

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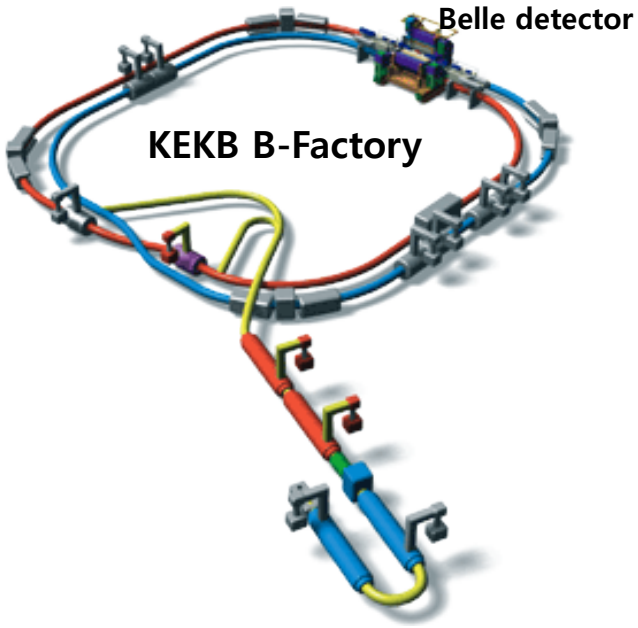
Contents

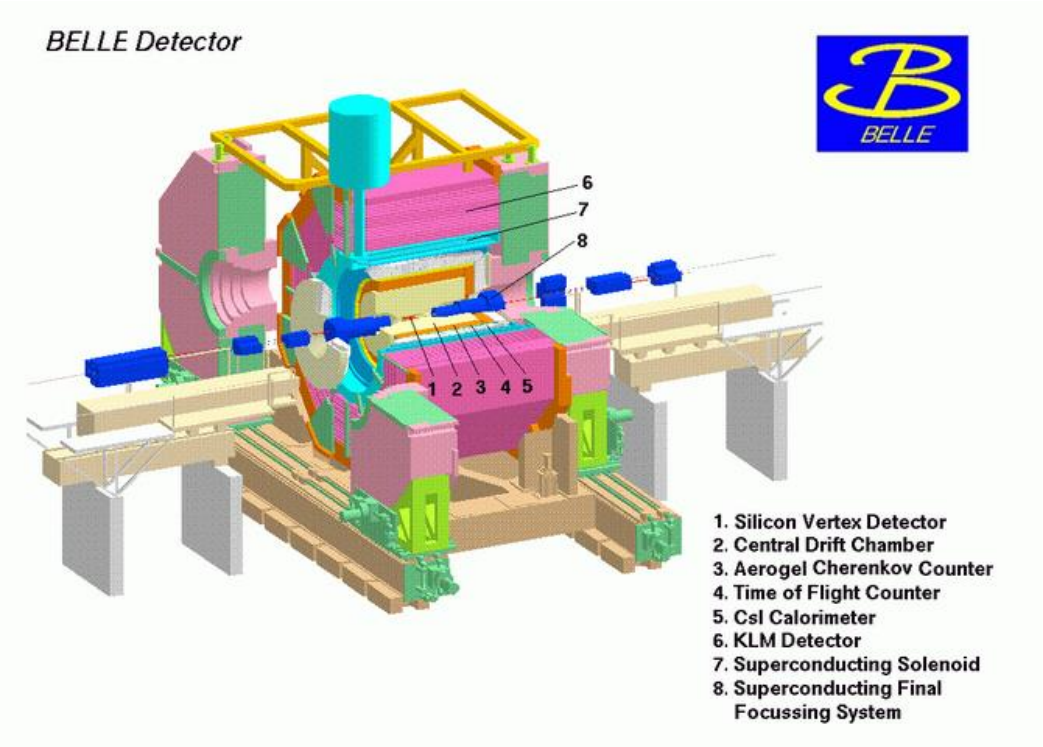
Belle experiment

Data collected with Belle detector at KEKB asymmetric e^+e^- collider : 3.5 GeV x 8 GeV

Total of 711 fb^{-1} of data collected at Y(4S)

→ 772M BB pairs





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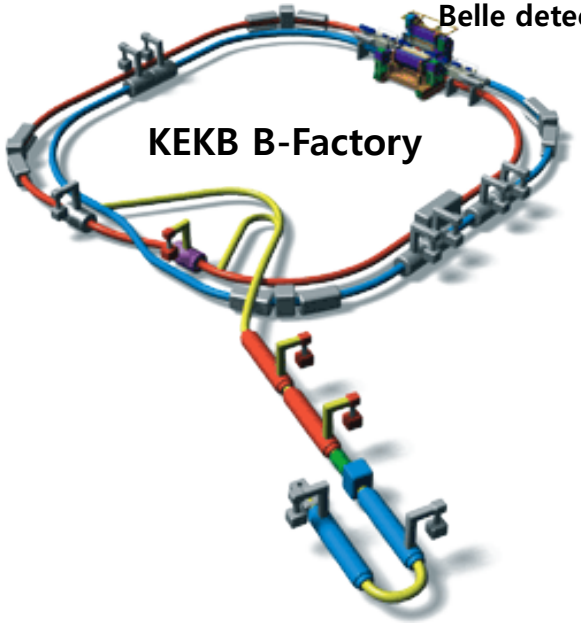
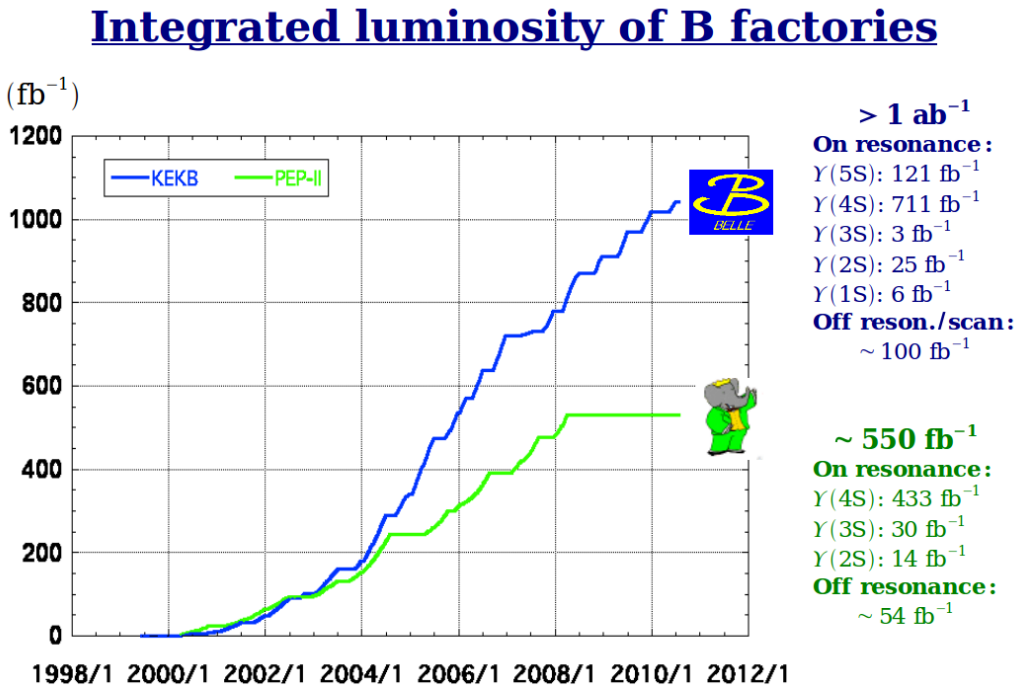
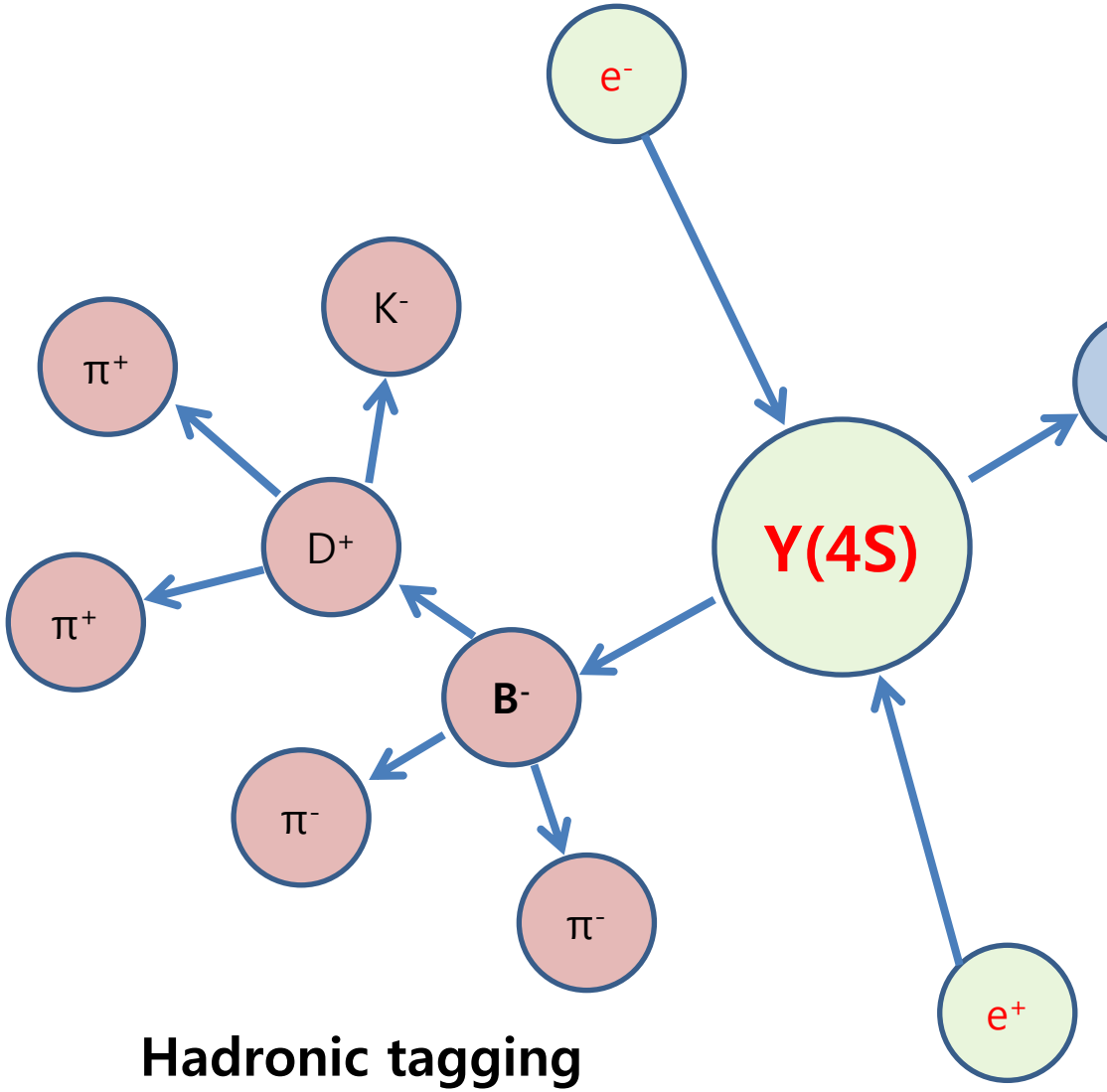






Hadronic tagging method

Invisible Particle X^0

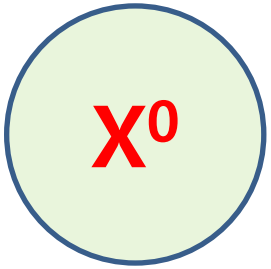
Mass range :
0.1 – 1.8 GeV/c^2

Spin : ½

Which can be X^0?

Motivation

Which is candidate?



Sterile neutrino in Large Extra Dimensions

K. Agashe, N.G. Deshpande, and G.-H. Wu, Phys. Lett. B 489, 367 (2000)

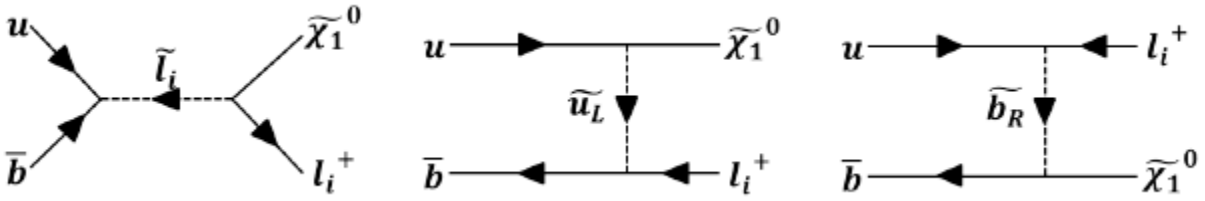
Heavy neutrino

T. Asaka and M. Shaposhnikokv, Phys. B 620, 17 (2005); D. Gorbunov and M. Shaposhnikov, J. High Energy Phys. 10 (2007) 015

Lightest neutralino in the SUSY with R-parity violation

A. Dedes and H. Dreiner, Phys. Rev. D 65, 015001 (2001)

Motivation



$$\Gamma(B^+ \to l_i^+ X) = \frac{\lambda'^2_{i13} g'^2 f_B^2 m_{B^+}^2 p_{l_i}^B}{8\pi(m_u + m_b)^2} \left(\frac{1}{2M_{\tilde{l}_i}^2} + \frac{1}{12M_{\tilde{u}_L}^2} + \frac{1}{6M_{\tilde{b}_R}^2} \right)^2 \left(m_{B^+}^2 - m_{l_i}^2 - m_{X^0}^2\right)$$

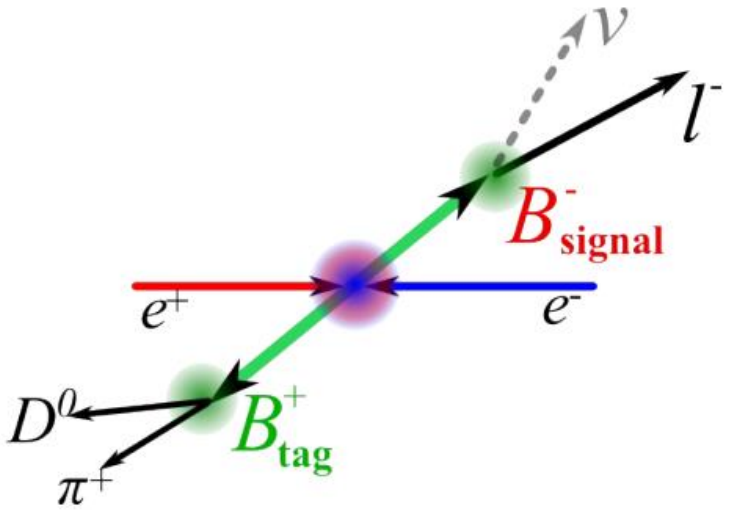
λ` : R-parity violating coupling constant

p_l^B : momentum of lepton at B rest frame

M_f~ : s-fermion mass

Any sensitivity of signal → New Physics!

Hadronic tagging method



Good suppression of $e^+e^- \rightarrow q\bar{q}$

(q = u,d,s,c)

Knowledge of charge, flavor,

four-momentum of B_{tag} and **B_{sig}** !

NIM A654, 432 (2011)

>96% of Y(4S) → BB with nothing else produced

one B-meson is completely reconstructed from known b → c decays without ν

efficiency is low, but purity is high

Good ways to reconstruct modes with invisible particle

Event selection

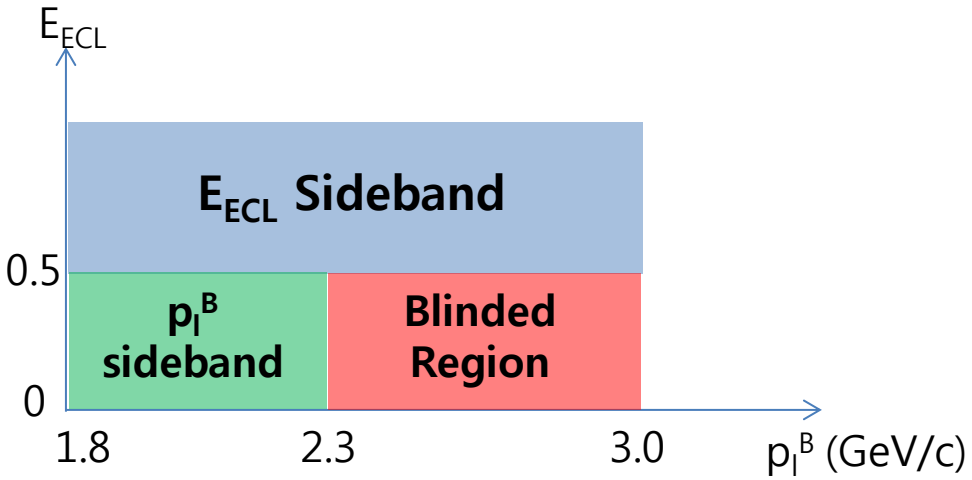
Particle Identity	Track quality	Continuum suppression
$L_e > 0.9$	$\|Dz\| < 2$ cm	$\|\cos\theta_{thrust}\| < 0.9$ for $B^+ \rightarrow e^+ X$
$L_\mu > 0.9$	$Dr < 0.5$ cm	$\|\cos\theta_{thrust}\| < 0.8$ for $B^+ \rightarrow \mu^+ X$

Quality of tagged-B meson

$|\Delta E| < 0.05$ GeV

$M_{bc} > 5.27$ GeV/c^2

$O_{NB} > e^{-6}$

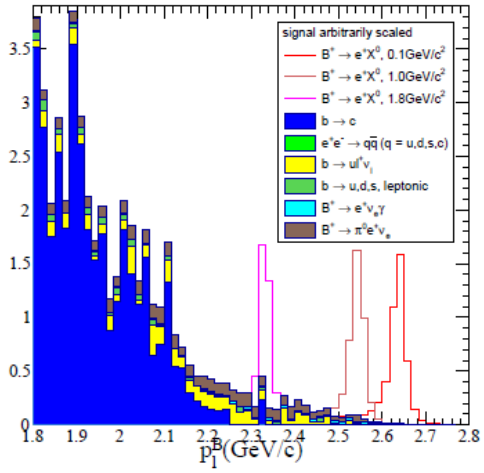


E_{ECL} : Remaining energy of ECL calorimeter (tagged-B & signal lepton)

p_l^B : signal lepton's momentum in the signal B rest frame

Upper limit of B.F.

$$\mathcal{B}(B^+ \to l^+ X^0) = \frac{N_{\rm obs} - N_{\rm exp}^{\rm bkg}}{2 \cdot \epsilon_s \cdot N_{B^+B^-}}$$



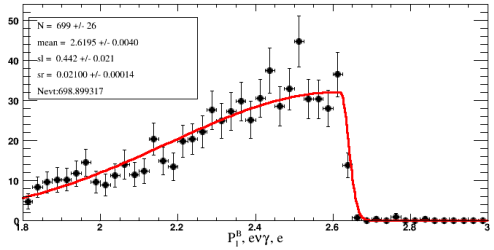
ε_s : efficiency of signal

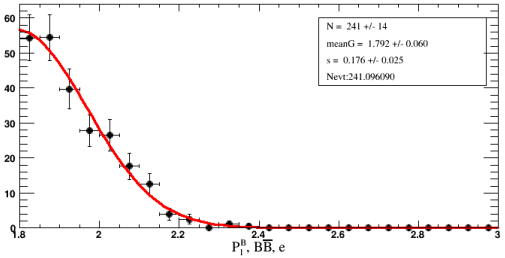
N_{B+B-} : Number of charged B meson pairs

N_{obs} : # of observed event in the signal criteria

N_{exp}^{bkg} : Expected background

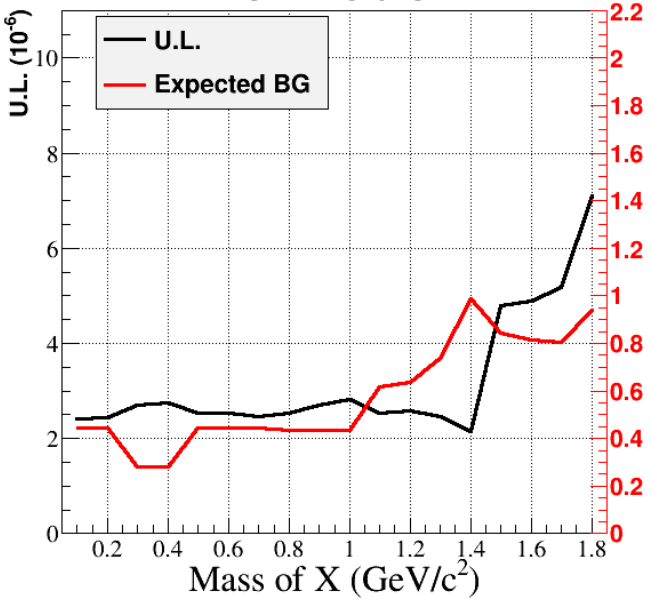
- using 1-D unbinned MaxLikelihood p_l^B fitting
- scaled with Data / MC ratio in sideband region



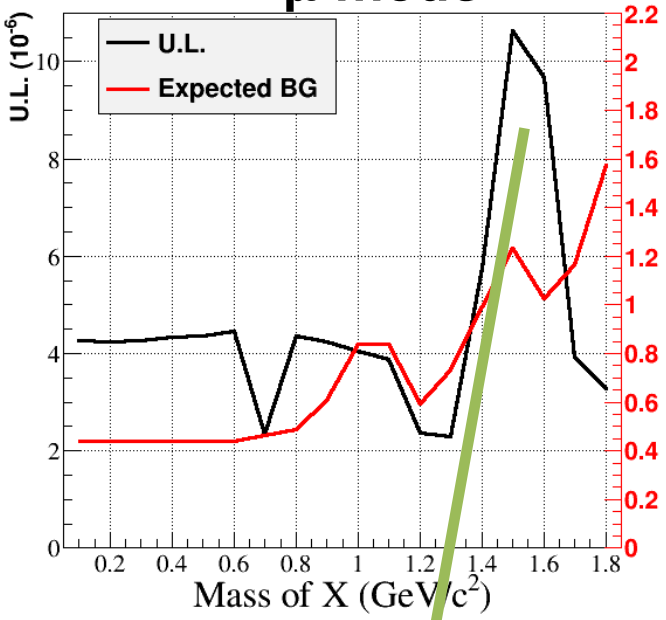


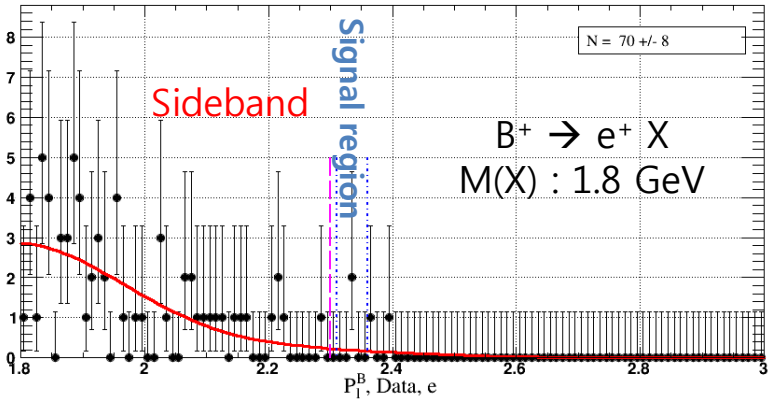
Upper limit of B.F.

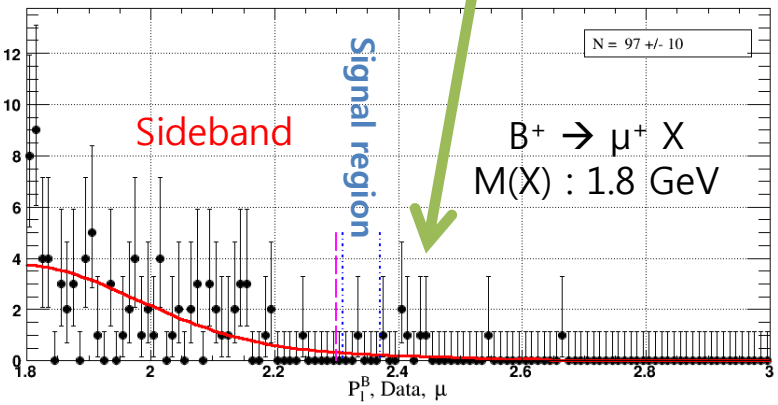
e mode



μ mode







Upper limit of B.F.

$$\xi_i = \lambda'^2_{i13}\left(\frac{1}{2M^2_{\tilde{l}_i}} + \frac{1}{12M^2_{\tilde{u}_L}} + \frac{1}{6M^2_{\tilde{b}_R}}\right)^2 = \frac{8\pi(m_u + m_b)^2\mathcal{B}(B^+ \to l_i^+ X^0)}{\tau_{B^+} g'^2 f_B^2 m^2_{B^+} p^B_{l_i}\left(m^2_{B^+} - m^2_{l_i} - m^2_{X^0}\right)}$$

From the branching fraction upper limits

We can set bounds on the SUSY-related parameter ξ_i

Most stringent upper bound on ξ_i

$\xi_1 < 3.95 \times 10^{-14}$

$\xi_2 < 4.11 \times 10^{-14}$

Summary

* We search for $B^+ \rightarrow l^+ X^0$, where X^0 can be any invisible (and possibly massive) spin-1/2 particle.
* We successfully suppressed background by help of hadronic tagging method.
* In preliminary results, the upper limits are $O(10^{-6})$
* Assuming RPV SUSY, we can set bounds on SUSY-related parameters
* This search comes into draft step, please ready for publication.

Thank you for listening!