High1-2014
KIAS-NCTS

Purely leptonic decays of *B* meson at Belle

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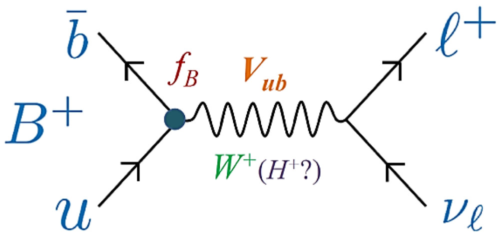
Motivation



$BR(B \to e\nu)_{SM} \sim 10^{-11}$
$BR(B \to \mu\nu)_{SM} \sim 3.5 \times 10^{-7}$
$BR(B \to \tau\nu)_{SM} \sim 10^{-4}$

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

<The Feynmann diagram, SM branching fraction, order of B.F$(B \to \ell^+\nu_\ell)$ >

Up-to-date results: $B \to \ell\nu$

(Loose Tagging)

$BR(B^+ \to e^+\nu_e) < 9.8 \times 10^{-7}$ $253 fb^{-1}$

Belle Collab., PLB 647, 67 (2007).

$BR(B^+ \to \mu^+\nu_\mu) < 1.0 \times 10^{-6}$ $426 fb^{-1}$

BABAR Collab., PRD 79, 091101 (2009).

(Hadronic Tagging)

$BR(B^+ \to e^+\nu_e) < 5.2 \times 10^{-6}$

$BR(B^+ \to \mu^+\nu_\mu) < 5.6 \times 10^{-6}$ $342 fb^{-1}$

BABAR Collab., PRD 77, 091104 (2008). ***@ 90% C.L.***

- A clean process for the measurement of f_B, $|V_{ub}|^2$, within the SM.
- Helicity suppression in the SM → $\mathrm{B.F.} \propto m_\ell^2$
- Deviation from the SM may reveal New Physics ! (e.g. 2HDM(type2), lepto-quark)
- Evidences of $B^+ \to \tau^+\nu_\tau$ from Belle and BABAR experiments.

2HDM type2

$$BR(B^+ \to \ell^+\nu_\ell)_{2HDM} = BR(B^+ \to \ell^+\nu_\ell) \times \left(1 - \tan^2\beta \frac{m_B^2}{m_H^2}\right)^2$$

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

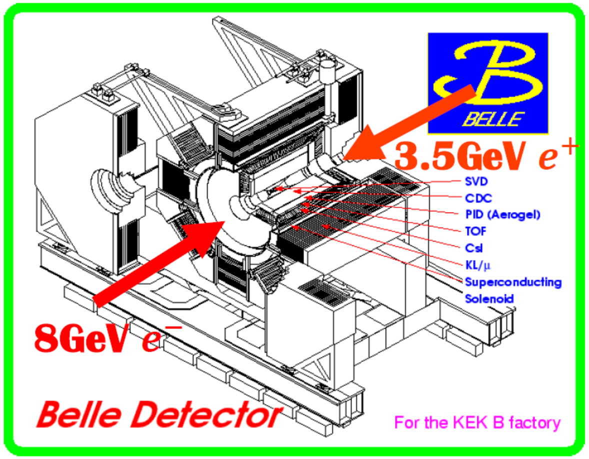
Result presented today is on…

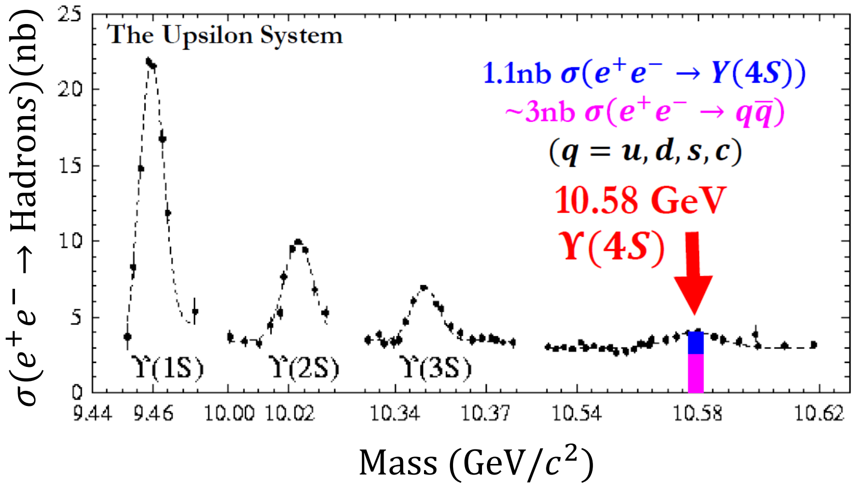
An update using full $\Upsilon(4S)$ data (772×10^6 $B\bar{B}$ events) / Hadronic tagging on $\ell = e, \mu$.

Hadronic Tagging

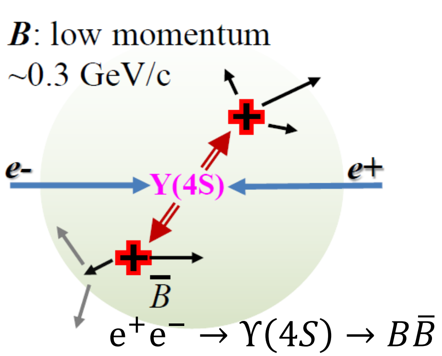
B-factories

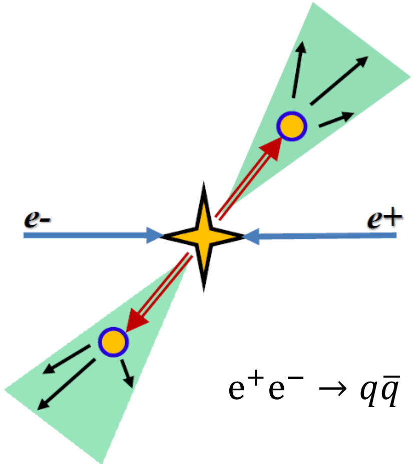
- Precise knowledge of the initial states in e^+e^- collisions.





- $Br(\Upsilon(4S) \to B\bar{B}) > 96\%$; w/ $p_B^* = 380\text{MeV}/c$

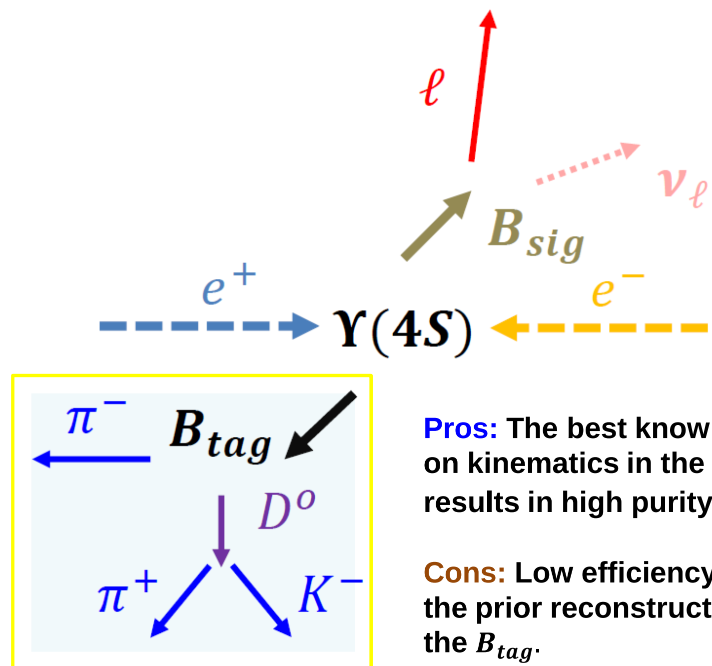




Hadronic Tagging

Definition:
Complete reconstruction of a B-meson (B_{tag}) in an $\Upsilon(4S) \to B\bar{B}$ decay via hadronic decay channels.

- Obtain the momentum of the signal side B meson with no additional effort.
    - Especially important for decays with limited access in the signal side.
    - $B^+ \to X\tau^+\nu_\ell; B \to X\nu\bar{\nu}$ ...
- High resolution in kinematical variables with B_{tag} quality control.
- Good continuum suppression.



Pros: The best knowledge on kinematics in the B_{sig} results in high purity !

Cons: Low efficiency due to the prior reconstruction of the B_{tag}.

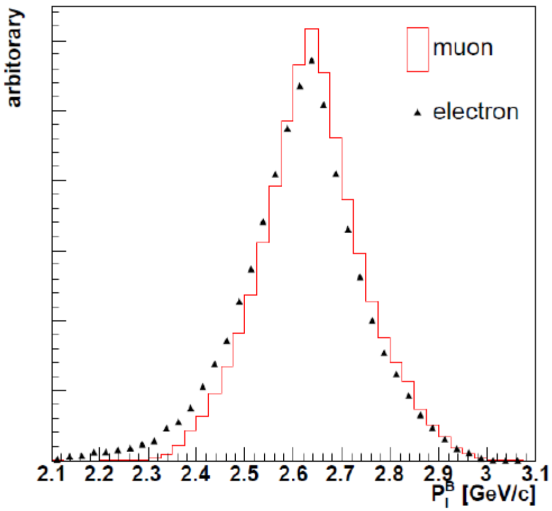
$$p(e^+) + p(e^-) = p(B) + p(\bar{B})$$
$$\mathrm{Br}(\Upsilon(4S) \to B\bar{B}) > 96\%$$
$$p_B^{CM} = 380\mathrm{MeV}/c \text{ : Spherical event shape}$$

Hadronic Tagging in $B^+ \to \ell^+ \nu_\ell$

Excuse me for a little bit of spoiler !

<Untagged Reconstruction> <Hadronic Tag. Reconstruction>

- The signal lepton candidate's momentum in B_{sig} rest frame. -

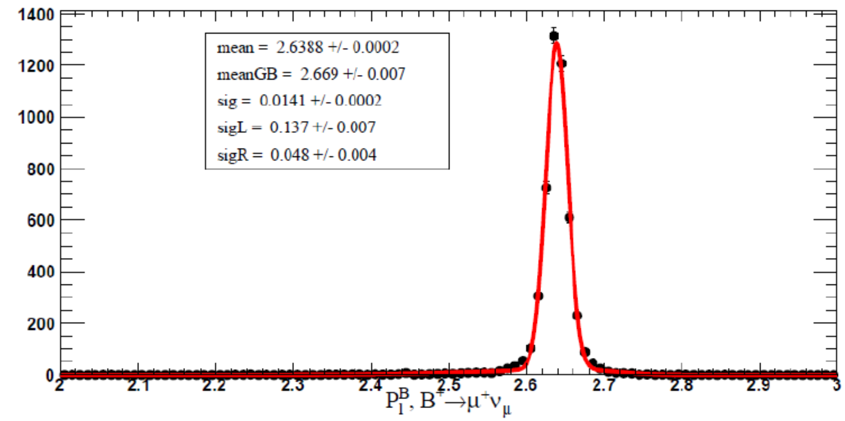


$\epsilon_{sig} = 2.18\%$

$N_{bkg} = 7.4 \pm 1.0$

Higher Efficiency

N. Satoyama (et al.) (Belle Collaboration), PLB 647, 67 (2007).



$\epsilon_{sig} = 0.104\%$

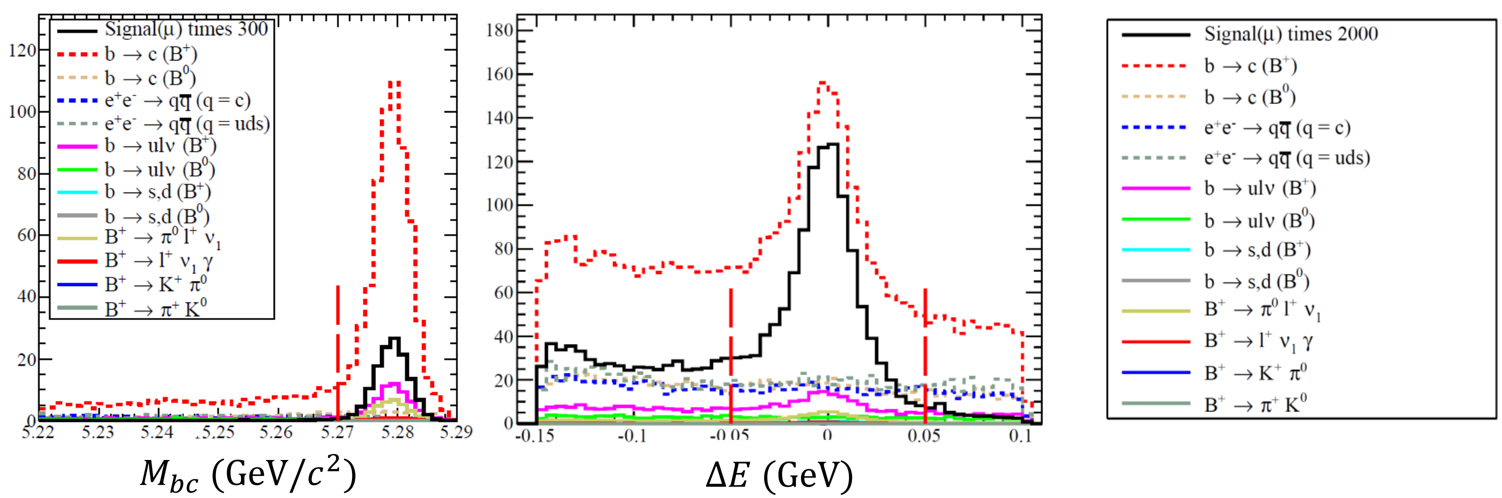
$N_{bkg} = 0.26^{+0.10}_{-0.08}$

An order better resolution.

Zero-continuum BG analysis.

In our analysis! : B_{tag} quality

- 615 B^+ channels with hierarchical reconstruction procedure.
- B_{tag} quality control via:
  - $M_{bc} = \sqrt{(E_{beam}/2)^2 - |\vec{p}_{Btag}|^2} > 5.27\text{GeV}/c$
  - $\Delta E = E_{Btag} - E_{beam}/2 : -0.05\text{ GeV} < |\Delta E| < 0.05\text{ GeV}$
  - o_{NB}: A neural network output.
    - More than one B_{tag} candidate in an event? → The highest o_{NB} candidate chosen.
    - $-\log(o_{NB}) < 6$ for quality control.



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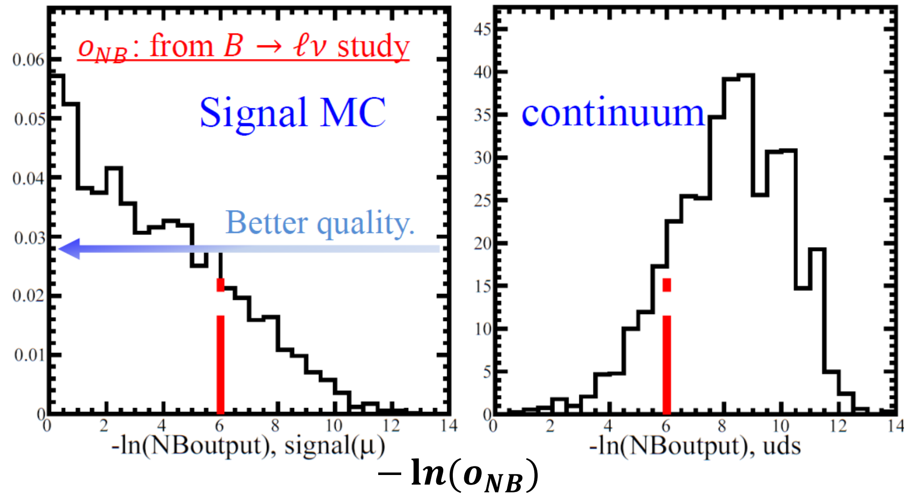
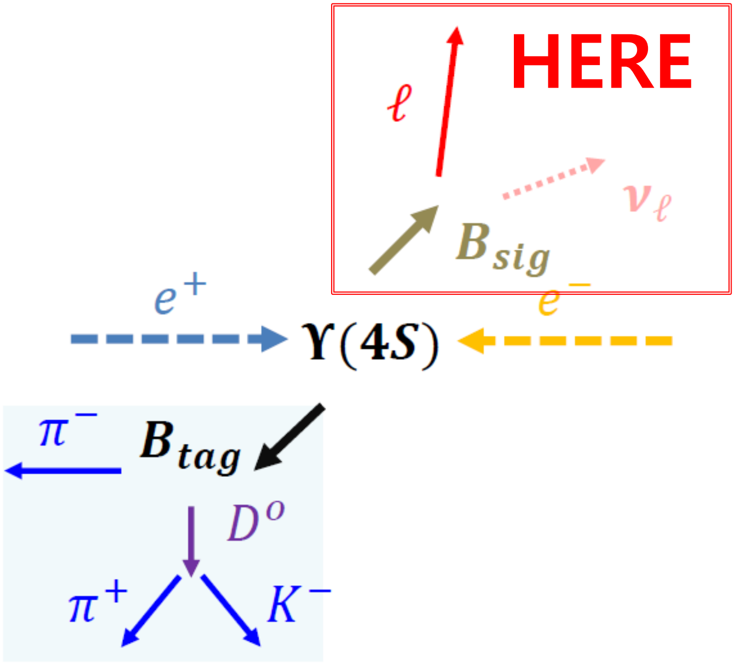


In our analysis! : ϵ_{tag}

- 615 B^+ channels with hierarchical reconstruction procedure.
- B_{tag} quality control via:
  - $M_{bc} = \sqrt{(E_{beam}/2)^2 - |\vec{p}_{Btag}|^2} > 5.27\text{GeV}/c$
  - $\Delta E = E_{Btag} - E_{beam}/2 : -0.05\text{ GeV} < |\Delta E| < 0.05\text{ GeV}$
  - o_{NB}: A neural network output.
    - More than one B_{tag} candidate in an event? → The highest o_{NB} candidate chosen.
    - $-\log(o_{NB}) < 6$ for quality control.
- ϵ_{tag} (B tagging efficiency) calibrated to data event by event.
  - A control sample study using $B \to D^{(*)}\ell\nu$ decays.
  - Calibrated in the o_{NB} value and the first hierarchy decay from the B_{tag}.
- $\epsilon_{tag} = 0.30\ (0.29)\%$ for $B \to \mu\nu$ ($B \to e\nu$).

Signal-side Event Selection

Now let's turn our focus to



A high momentum lepton & an invisible neutrino.

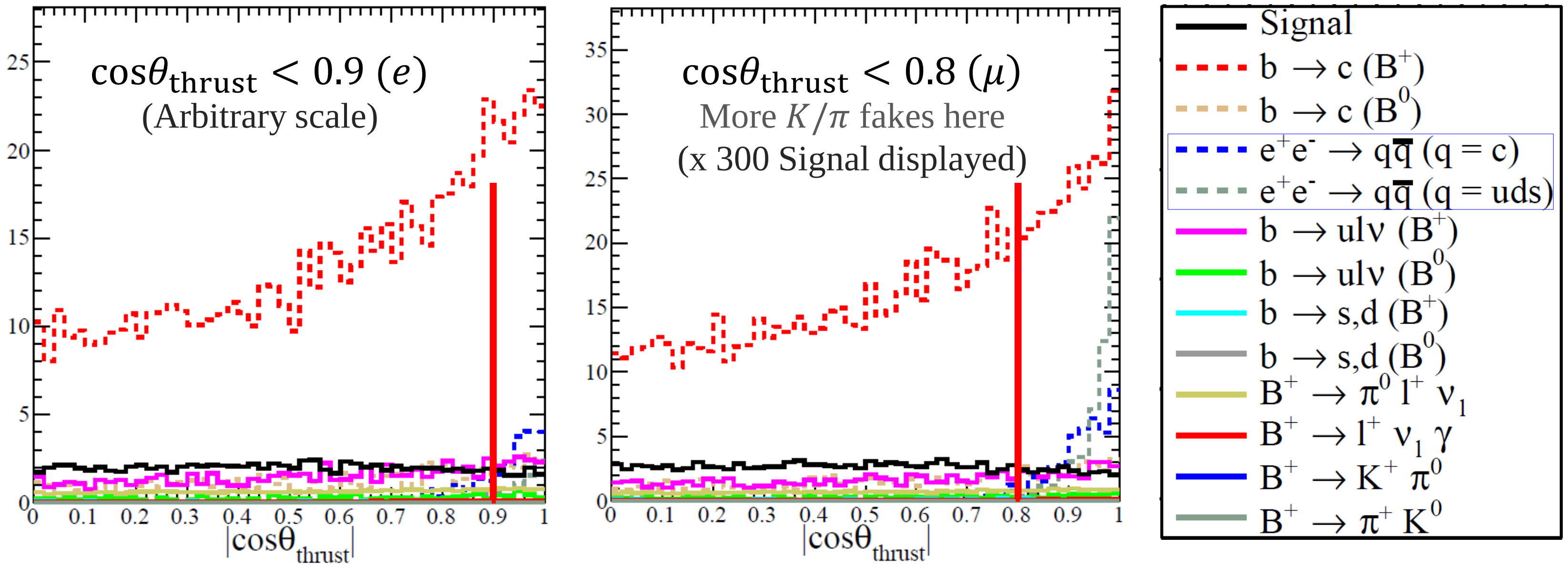
Pre-selection of events with a lepton with $p_\ell^{LAB} > 1.8$ GeV/c.

Impact parameter conditions to sort good tracks.

(distance from the IP: dr < 0.05cm, |dz| < 1.5cm)

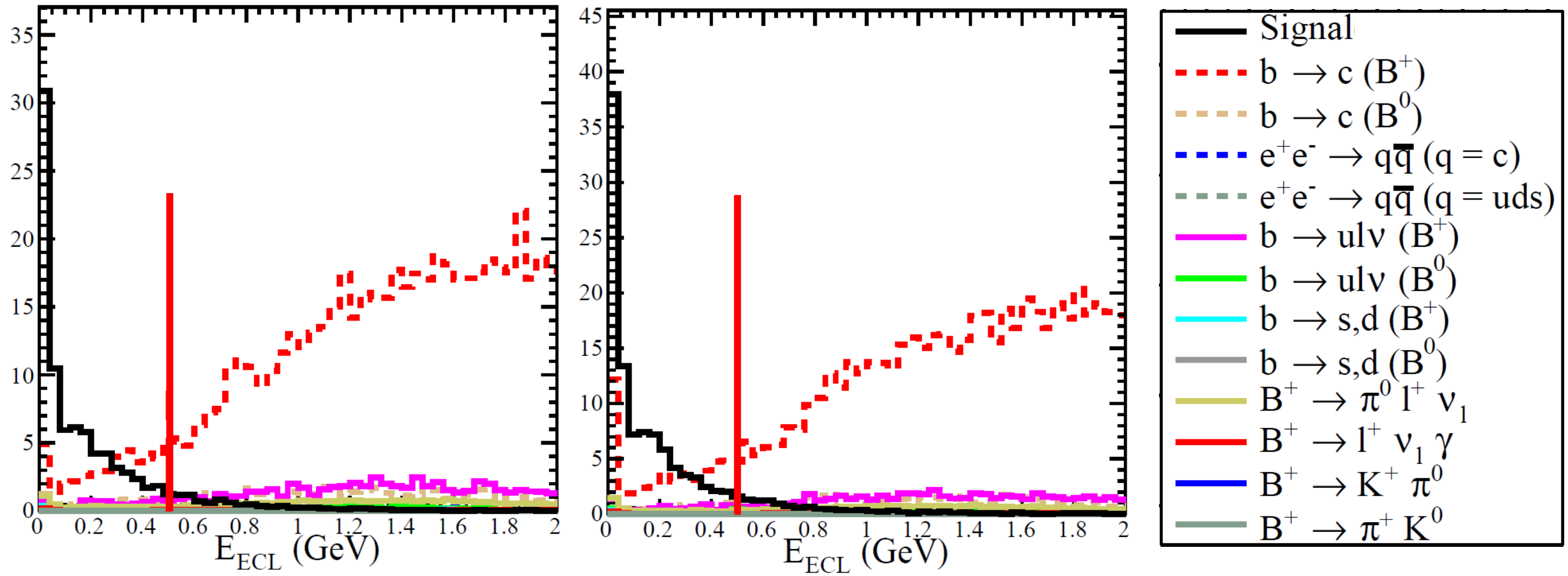
Continuum suppression

- Virtual extermination using $\cos\theta_{thrust}$.
  - θ_{thrust}: $\angle\,(B_{\text{tag}}$ thrust axis, $\vec{p}_{\ell}^{\,*})$



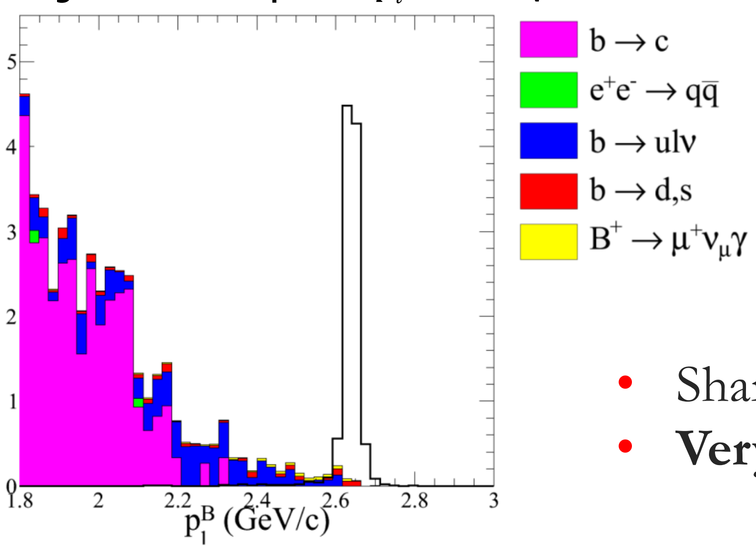
Further BG suppression

- $E_{ECL} = E_{Total} - E_{Btag} - E_{\ell}$
  - No extra particles aside from the B_{tag} and the signal ℓ.



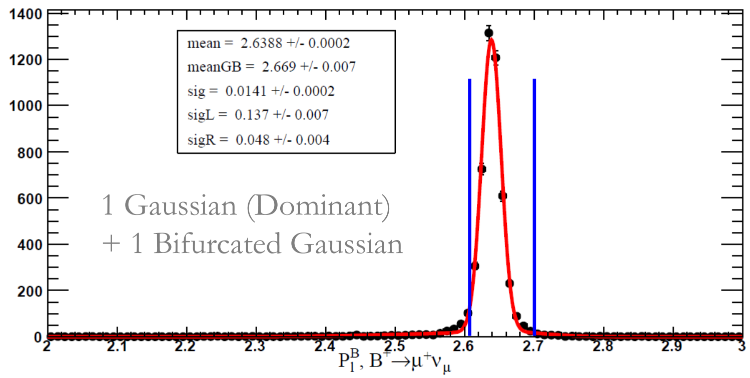
Signal Extraction Variable

<Signal Enhanced plot of p_ℓ^B for $B \to \mu\nu$ search>



$\boldsymbol{p_\ell^B}$: The momentum of the signal ℓ at the rest frame of the B_{sig}.

- Sharp-peaking near 2.64 GeV/c due to 2-body decay.
- **Very clean signal separation with low BG.**

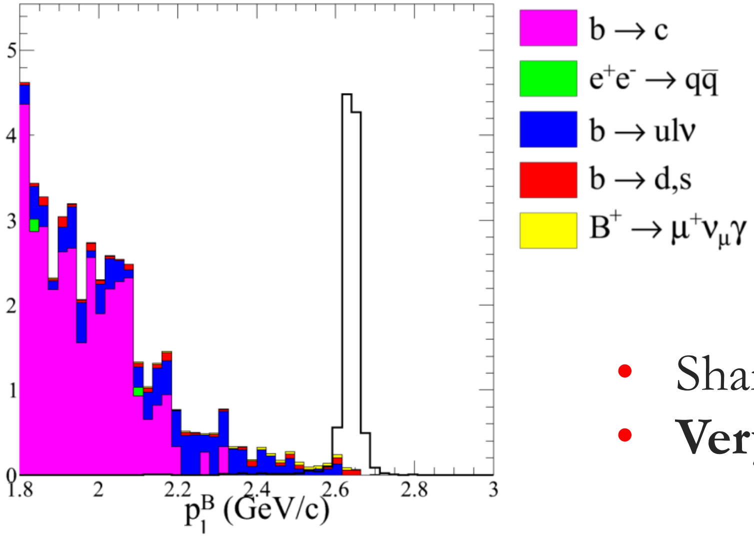


Signal region decision

- -2.5σ of the main Gaussian component in the histogram fit $< p_\ell^B < 2.7$ GeV$/c$.
  - e: 2.606 GeV$/c < p_\ell^B < 2.7$ GeV$/c$
  - μ: 2.604 GeV$/c < p_\ell^B < 2.7$ GeV$/c$

Signal Extraction Variable

<Signal Enhanced plot of p_ℓ^B for $B \to \mu\nu$ search>



$\boldsymbol{p_\ell^B}$: The momentum of the signal ℓ at the rest frame of the B_{sig}.

- Sharp-peaking near 2.64 GeV/c due to 2-body decay.
- **Very clean signal separation with low BG.**

$$BR = \frac{Y_{data} - N_{bkg}^{MC}}{N_{B\bar{B}} \cdot \epsilon_{signal}}$$

Y_{data}: Observed data yield in the signal region.
N_{bkg}^{MC}: Expected backgrounds in the signal region.
$N_{B\bar{B}}$: Initial # of $B\bar{B}$.
ϵ_{sig}: Signal selection efficiency

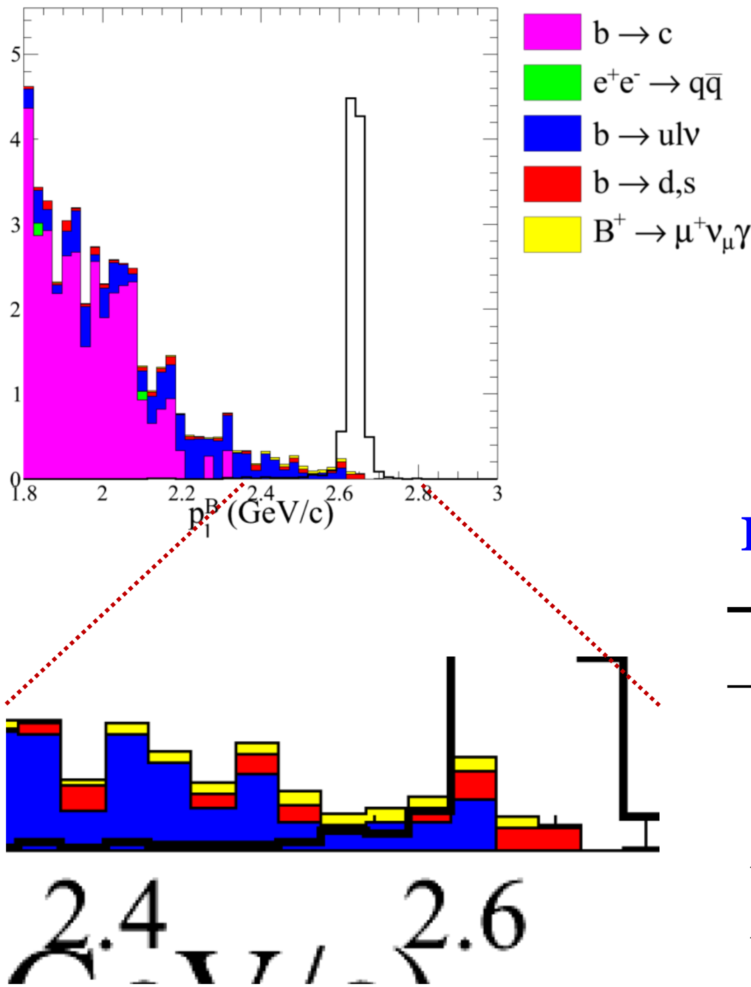
Signal extraction strategy!

$\boldsymbol{Y_{data}}$: count the events in the p_ℓ^B signal region.

$\boldsymbol{N_{bkg}^{MC}}$: extrapolate from the background PDF fit to the side band data. The PDF's are obtained from the mode-by-mode histogram template 1D unbinned maximum likelihood fit.

Signal Extraction Variable

<Signal Enhanced plot of p_ℓ^B for $B \to \mu\nu$ search>



N_{bkg}^{BG}

Estimation of backgrounds crucial in this study!

Peaking / heavily influential decays in the signal region treated with dedicated large MC samples.

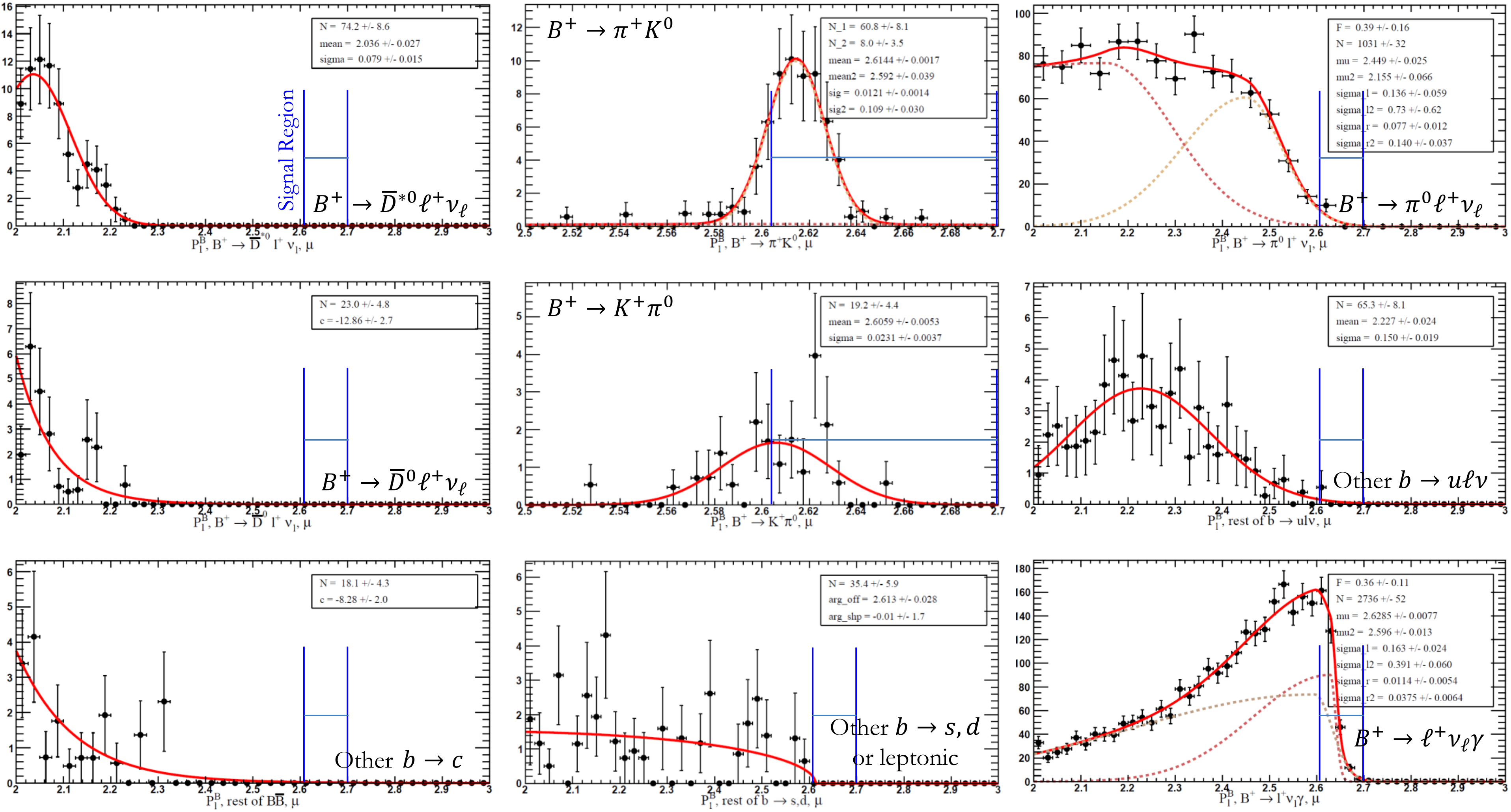
$b \to c$ decays, dominant in the low momentum range, composed of over 90% of $B^- \to D^{(*)0}\ell^-\bar{\nu}$.

Expected from the MC histograms (Events)

	Backgrounds: $B \to \mu\nu$	Backgrounds: $B \to e\nu$
$\boldsymbol{b \to u\ell\nu}$	0.0087 (13.8%)	0.0289 (13.0%)
Other $\boldsymbol{X_u\ell\nu}$	0	0.0598 (26.9%)
$\boldsymbol{B^+ \to \pi^+K^0}$	0.0410 (65.1%)	0.0612 (27.6%)
$\boldsymbol{B^+ \to K^+\pi^0}$	0.0133 (21.1%)	0.0631 (28.4%)
$\boldsymbol{B^+ \to \ell^+\nu_\ell\gamma}$	0	0.0091 (4.1%)
Total	0.063	0.222

$B \to \ell\nu\gamma$ according to G. Korchemsky, D. Pirjol, and T.-M. Yan, PRD 61, 114510 (2000) Assumed $BR(B \to \ell\nu\gamma) = 5.0 \times 10^{-6}$

Background PDFs from histogram template fits

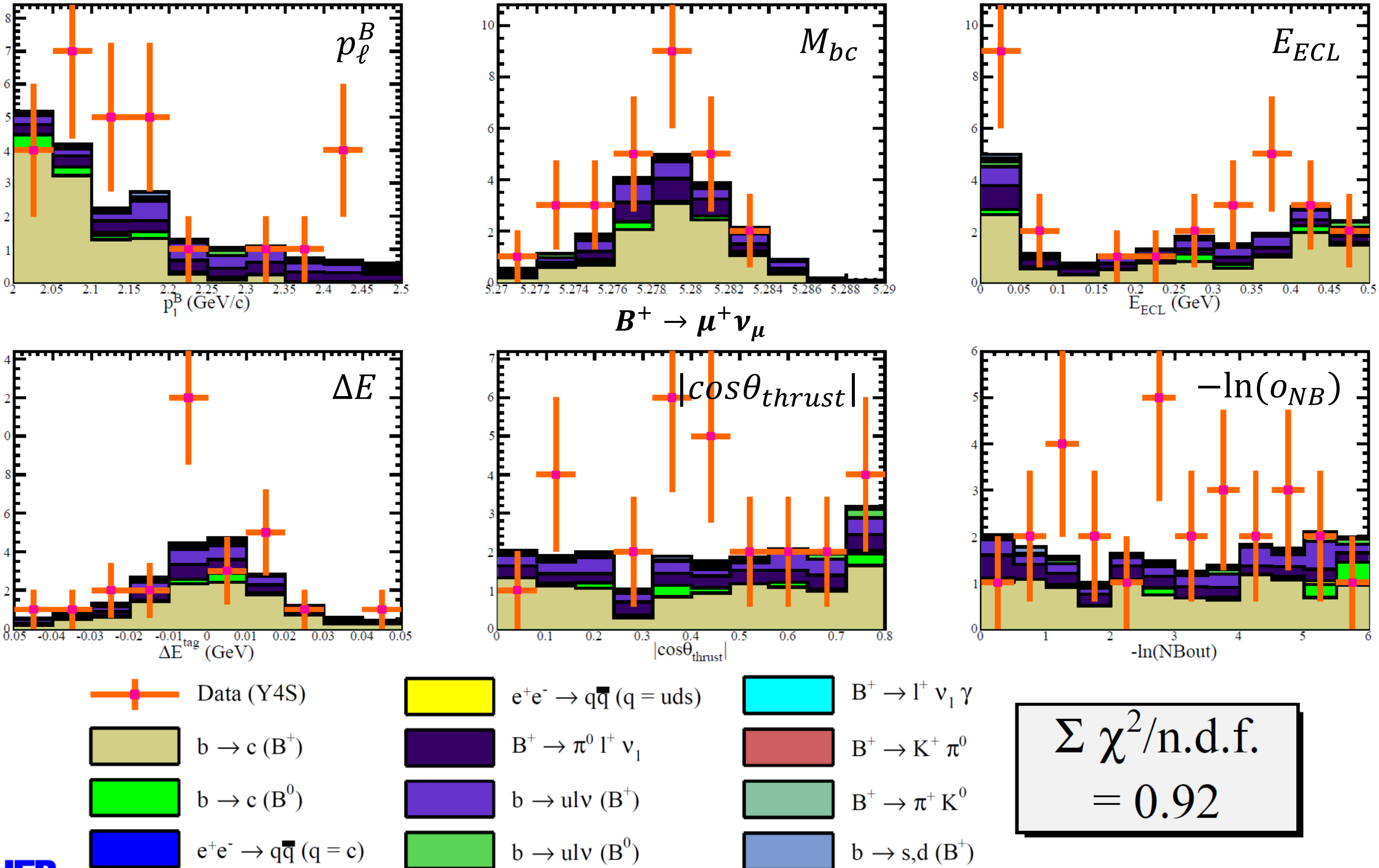


- $B^+ \to \mu^+\nu_\mu$ mode
- Backgrounds PDFs summed w/ branching ratio weighting

Verification

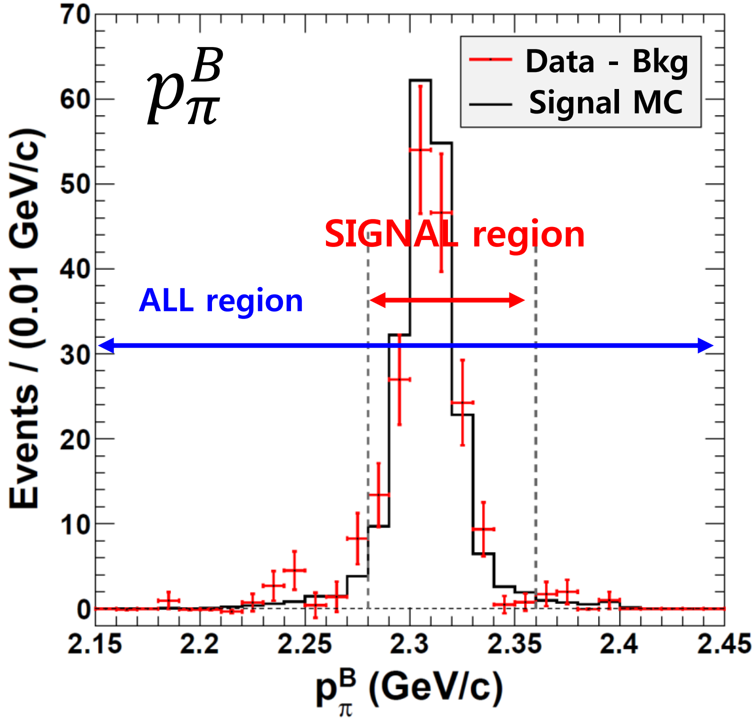
MC compared w/ data in the p_ℓ^B sideband region

- p_ℓ^B sideband region $\equiv 2.0 - 2.5\ \mathrm{GeV}/c$, all other criteria applied.



p_ℓ^B shape calibration

- A control sample study using:
  - $B^+ \to \overline{D}^0 \pi^+ : D^0 \to K^- \pi^+$ & $D^0 \to K^-(3\pi)^+$.
  - Treat π^+ (primary pion) as ℓ^+, D^0 as ν_ℓ.
  - Same conditions given for $B^+ \to \ell^+ \nu_\ell$ analysis given.



Fitted each distribution and integrated each region.

$$C_{shape} \equiv \frac{N_{sig}(\text{Data} - \text{Bkg})/N_{all}(\text{Data} - \text{Bkg})}{N_{sig}(\text{signal MC})/N_{all}(\text{signal MC})}$$

$$= 0.954^{+0.033}_{-0.031}$$

Obtained BR within 0.2σ deviation compared to the PDG world average.

(Including systematic uncertainties from $K\pi$-ID / C_{shape} / tag / PDF parameters / tracking uncertainties.)

Signal Extraction & Branching Ratio

Systematic Uncertainties

$$BR = \frac{Y_{data} - N_{bkg}^{MC}}{N_{B\bar{B}} \cdot \epsilon_{signal}}$$

- PDF uncertainty in parameters from the fit.
- Branching Ratio uncertainty.
- Statistical uncertainty of the experimental data in the sideband region.

$N_{bkg}^{MC}(e) = 0.11^{+0.08}_{-0.06}$ events

$N_{bkg}^{MC}(\mu) = 0.33^{+0.10}_{-0.08}$ events

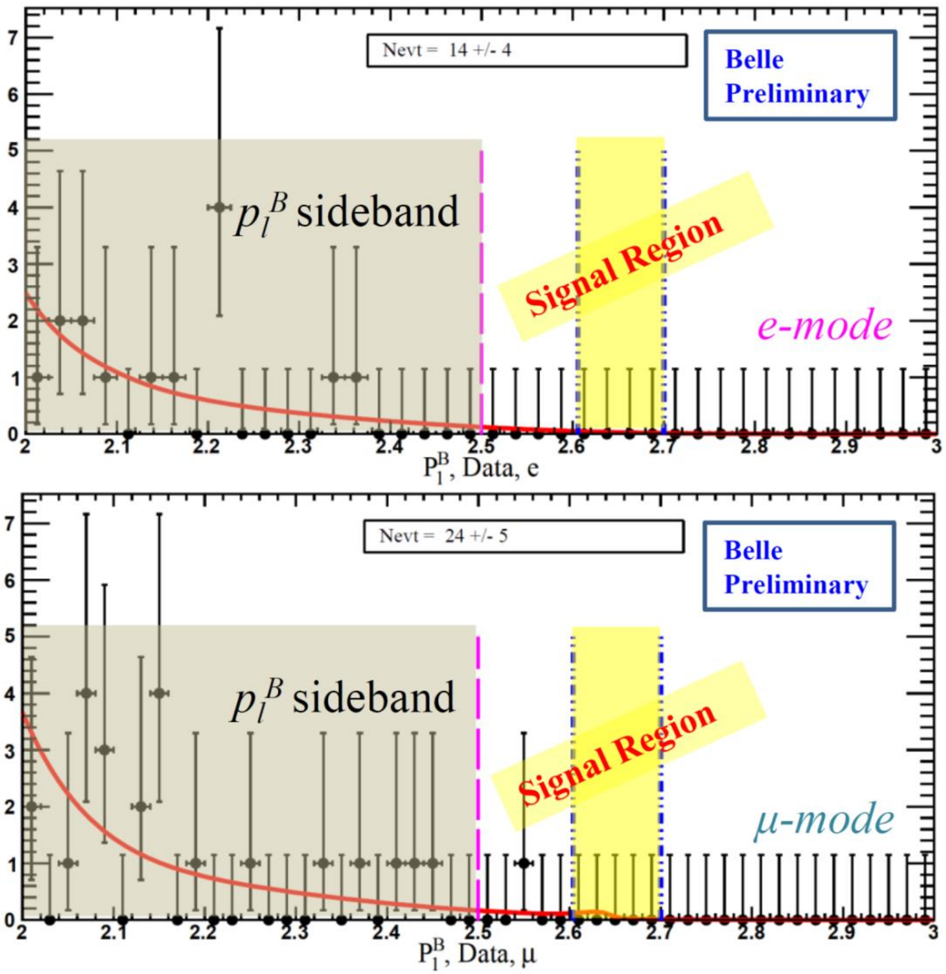
Sources	Uncertainty
$N_{B\bar{B}}$	1.4 %
ϵ_{tag} correction	4.2 %
Lepton Identification	2.1 %
Tracking	0.35 %
MC statistics	2.0 %
p_ℓ^B shape	15.2 %
Sum	16.0 %

$\epsilon_{signal}(e) = 0.091\%$
$\epsilon_{signal}(\mu) = 0.115\%$

A note on the $\mathbf{p}_\ell^B$ *shape!*

The number here is based on the preliminary result. The study in p.21 was a modification after the preliminary result was presented, and the updated number will be presented in the paper soon to be submitted. In the updated the systematic uncertainty is reduced at ~6%, along with slightly modified ϵ_{signal} and N_{bkg}^{MC}. Very sorry about that!

Opening the p_ℓ^B signal region



We observe no experimental data events in the p_ℓ^B signal region.

	$B^+ \to \mu^+\nu\_\mu$	$B^+ \to e^+\nu_e$
Y_{data}	0	0
ϵ_{signal}	0.115% (16% unc.)	0.091% (16% unc.)
N_{bkg}^{MC}	$0.33^{+0.10}_{-0.08}$	$0.11^{+0.08}_{-0.06}$

$$BR(B^+ \to \mu^+\nu_\mu) < 2.5 \times 10^{-6}\ (90\%\ C.L.)$$

$$BR(B^+ \to e^+\nu_e) < 3.5 \times 10^{-6}\ (90\%\ C.L.)$$

Upper limits calculated based on a frequentist approch,
Feldman & Cousins method.
(G. J. Feldman and R. D. Cousins, PRD 57, 3878 (1998).)

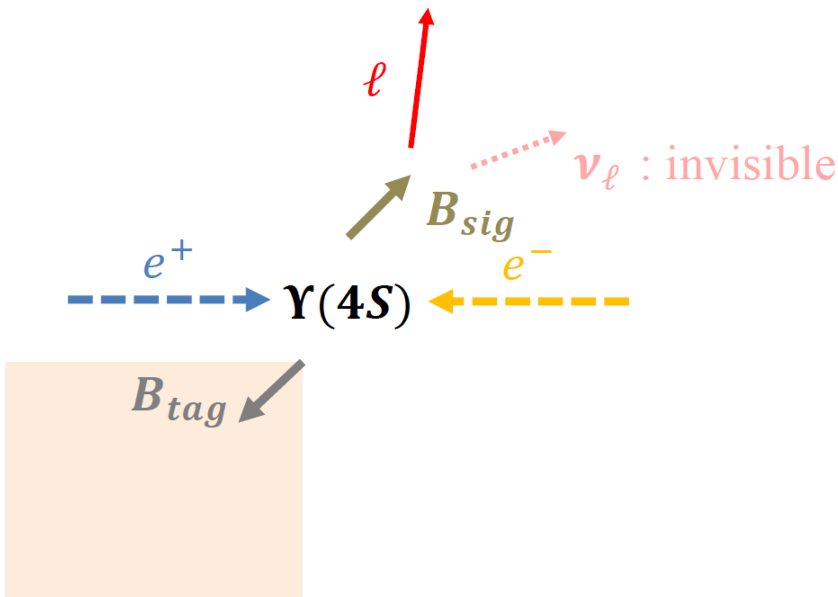
Summary

- With 772M $B\bar{B}$ events and hadronic tagging method, we search for the purely leptonic rare B meson decays, $B^+ \to e^+\nu_e$ and $B^+ \to \mu^+\nu_\mu$.
- We obtain the most stringent "hadronic tagging method using" constraint, improved by a factor of two.
- The low background study demonstrated shows a promise of hadronic tagging method as a powerful probe for testing the SM and searching for the New Physics.
- The paper draft to be submitted soon with the final results.

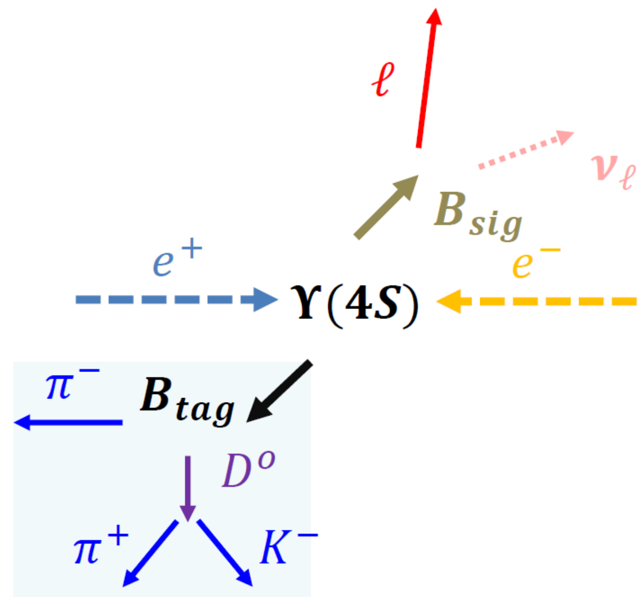
BACK UP

Untagged study vs. Hadronic Tag.

- The two extremes of reconstruction.
  - **A simple depiction with $B^+ \to \ell^+ \nu_\ell$ search.**



<Untagged Reconstruction>



<Hadronic Tag. Reconstruction>

s: Higher efficiency due
10 prior reconstruction.

s: Many combinatorial
kgrounds and worse B_{tag}
ted variable resolution.

Efficiency ←

→ **Purity**

Pros: The best knowledge on kinematics in B_{sig} results in high purity.

Cons: Lower efficiency due to prior reconstruction.

Had. Tagging Hierarchy

B^+	B^0
$B^+ \to \bar{D}^0\pi^+$	$B^0 \to D^-\pi^+$
$B^+ \to \bar{D}^0\pi^+\pi^0$	$B^0 \to D^-\pi^+\pi^0$
$B^+ \to \bar{D}^0\pi^+\pi^+\pi^-$	$B^0 \to D^-\pi^+\pi^+\pi^-$
$B^+ \to D_S^+\bar{D}^0$	$B^0 \to \bar{D}^0\pi^0$
$B^+ \to \bar{D}^{0*}\pi^+$	$B^0 \to D_S^+D^-$
$B^+ \to \bar{D}^{0*}\pi^+\pi^0$	$B^0 \to D^{*-}\pi^+$
$B^+ \to \bar{D}^{0*}\pi^+\pi^+\pi^-$	$B^0 \to D^{*-}\pi^+\pi^0$
$B^+ \to \bar{D}^{0*}\pi^+\pi^+\pi^-\pi^0$	$B^0 \to D^{*-}\pi^+\pi^+\pi^-$
$B^+ \to D_S^{+*}\bar{D}^0$	$B^0 \to D^{*-}\pi^+\pi^+\pi^-\pi^0$
$B^+ \to D_S^+\bar{D}^{0*}$	$B^0 \to D_S^{+*}D^-$
$B^+ \to D_S^{+*}\bar{D}^{0*}$	$B^0 \to D_S^+D^{*-}$
$B^+ \to \bar{D}^0K^+$	$B^0 \to D_S^{+*}D^{*-}$
$B^+ \to D^-\pi^+\pi^+$	$B^0 \to J/\psi K_S^0$
$B^+ \to J/\psi K^+$	$B^0 \to J/\psi K^+\pi^-$
$B^+ \to J/\psi K^+\pi^+\pi^-$	$B^0 \to J/\psi K_S^0\pi^+\pi^-$
$B^+ \to J/\psi K^+\pi^0$	
$B^+ \to J/\psi K_S^0\pi^+$	

TABLE XV. Stage 4 - All B modes

D^0	D^+	D_S
$D^0 \to K^-\pi^+$	$D^+ \to K^-\pi^+\pi^+$	$D_S^+ \to K^+K_S^0$
$D^0 \to K^-\pi^+\pi^+\pi^-$	$D^+ \to K_S^0\pi^+$	$D_S^+ \to K^+\pi^+\pi^-$
$D^0 \to K^-\pi^+\pi^0$	$D^+ \to K_S^0\pi^+\pi^0$	$D_S^+ \to K^+K^-\pi^+$
$D^0 \to \pi^+\pi^-$	$D^+ \to K^-\pi^+\pi^+\pi^0$	$D_S^+ \to K^+K^-\pi^+\pi^0$
$D^0 \to \pi^+\pi^-\pi^0$	$D^+ \to K_S^0\pi^+\pi^+\pi^-$	$D_S^+ \to K^+K_S^0\pi^+\pi^-$
$D^0 \to K_S^0\pi^0$	$D^+ \to K^+K^-\pi^+$	$D_S^+ \to K^-K_S^0\pi^+\pi^+$
$D^0 \to K_S^0\pi^+\pi^-$	$D^+ \to K^+K^-\pi^+\pi^0$	$D_S^+ \to K^+K^-\pi^+\pi^+\pi^-$
$D^0 \to K_S^0\pi^+\pi^-\pi^0$		$D_S^+ \to \pi^+\pi^+\pi^-$
$D^0 \to K^+K^-$	$J/\psi \to e^-e^+$	
$D^0 \to K^+K^-K_S^0$	$J/\psi \to \mu^-\mu^+$	

TABLE XIII. Stage 2 - All D and J/ψ modes

D^{*+}	D^{*0}	D_S^*
$D^{+*} \to D^0\pi^+$	$D^{0*} \to D^0\pi^0$	$D_S^{+*} \to D_S^+\gamma$
$D^{+*} \to D^+\pi^0$	$D^{0*} \to D^0\gamma$	

TABLE XIV. Stage 3 - all D^* modes

Variables used in the NN training

- Only including the variables for the higher hierarchy reconstruction due to the page-shortage reason.

Name	Variable
sumChldNB	Sum of the NeuroBayes outputs of all of the children
prodChildNB	Product of the NeuroBayes outputs of all of the children
ptot	$\lvert p \rvert$
ChN_ptot	$\lvert p \rvert$ of child N
ChN_NBout	NeuroBayes output of child N
ChN_PseudoHelAng	Angle between the child momentum in the mother's rest frame and the mother's direction in the $\Upsilon(4S)$ rest frame. For D meons, this really is a good approximation of the helicity angle.
ChN_hash	Decay hash of child N
ChN_Mass	Mass of child N
ChMN_Angle	Angle between children N and M in the CMS
ChMN_InvMassScaled	Invariant mass of children N and M, scaled to the maximum (=1) and minimum (=0) possible theoretical value.
mom_dir_dev	Angle between the momentum of the D meson and the line connecting the IP and the fitted D vertex.
dist_to_IP	Distance of the fitted D vertex and the IP
sig_dist_to_IP	Significance of the distance of the fitted D vertex and the IP
deltaE	ΔE
Dstar_D_massdiff	$M(D^*) - M(D)$
D_hash_from_1st_dstar	Decay hash from the first D^* meson
D_hash_from_2nd_dstar	Decay hash from the second D^* meson
CosThetaB	$\cos\theta_B$
ChN_D_dist	Distance of closest approach of a track from the B decay to the fitted vertex of the D meson

TABLE XXIII. Variables used in the stage 2, 3 and 4 trainings

ϵ_{tag} calibration

$$x \equiv \ln NB_{\text{out}}$$

$$F^{\text{DATA}}(x)/F^{\text{MC}}(x) \equiv C(x)$$

$$F(x) = \int_x^0 f(z)dz$$

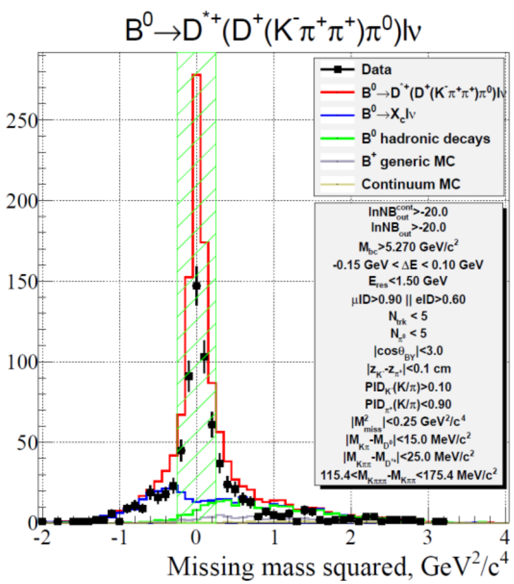
$\ln(NB_{out})$ distribution

(# event in within $\ln(NB_{out})$ cut.)

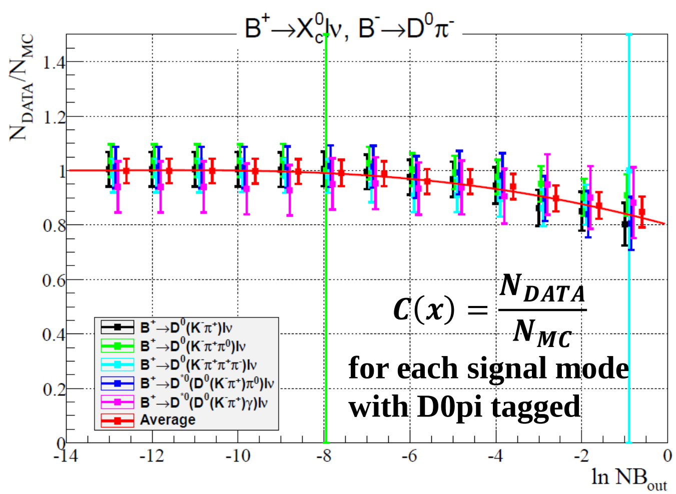
<with these definitions>

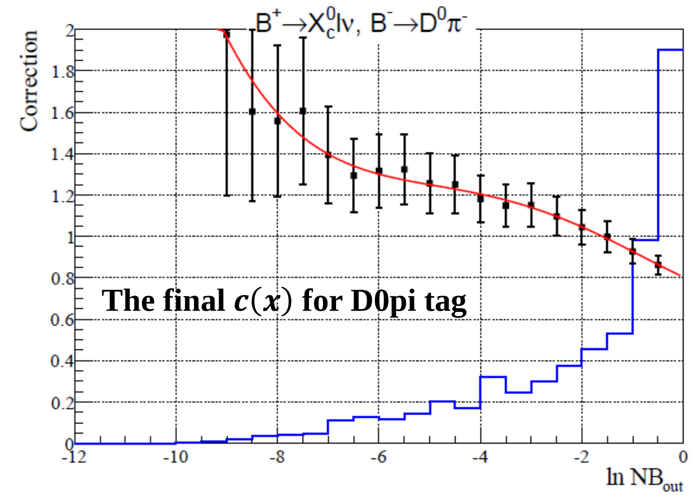
$$c(x) = \frac{f^{\text{DATA}}(x)}{f^{\text{MC}}(x)} = C(x) - \frac{F^{\text{MC}}(x)}{f^{\text{MC}}(x)} \frac{\text{d}C(x)}{\text{d}x}$$

The correlation factor can be expressed as a function of NB_{out}. This is done for each tagged decay structure.



overall MM2 distribution of the specified signal





o_{NB} in terms of Efficiency and Purity

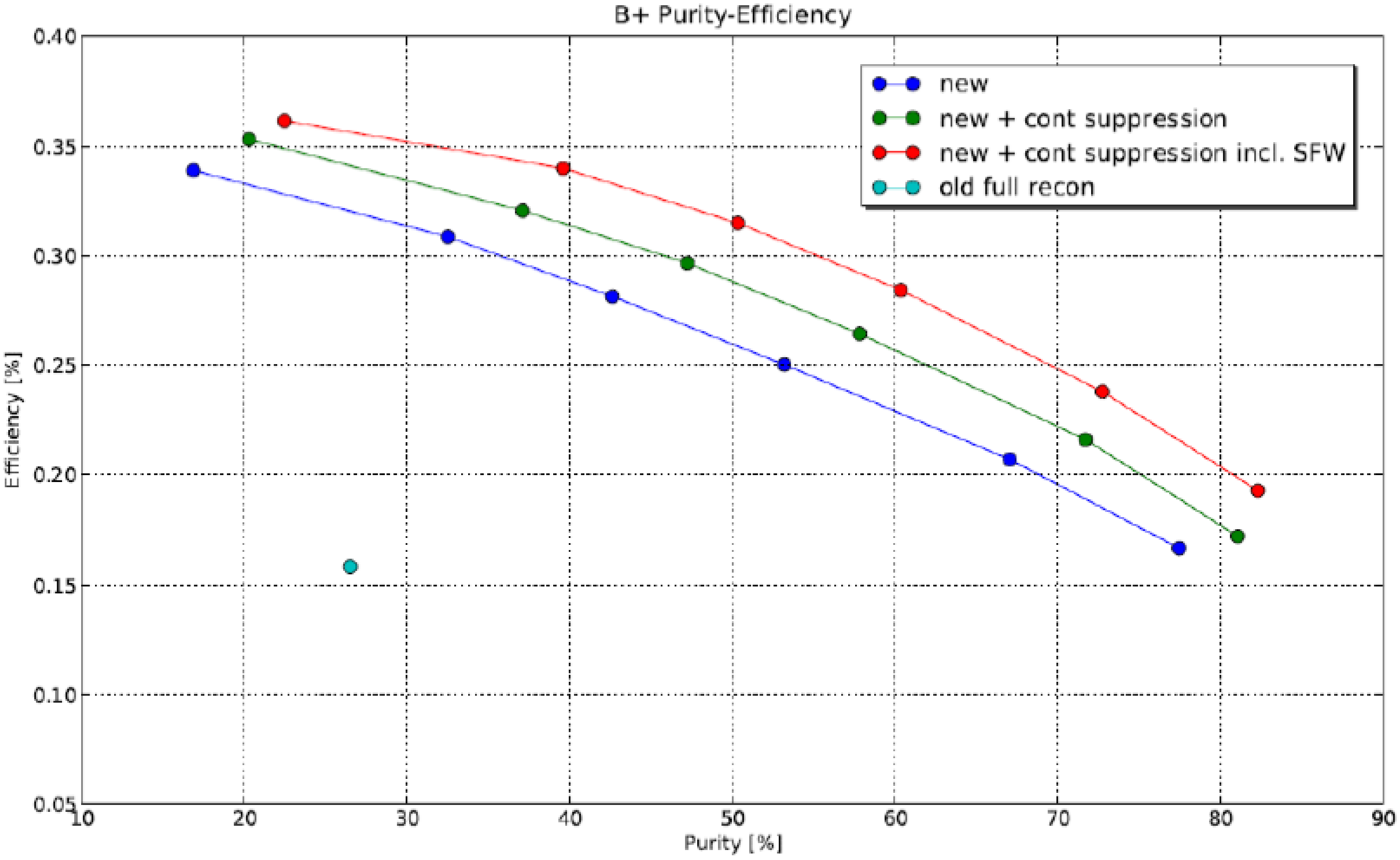
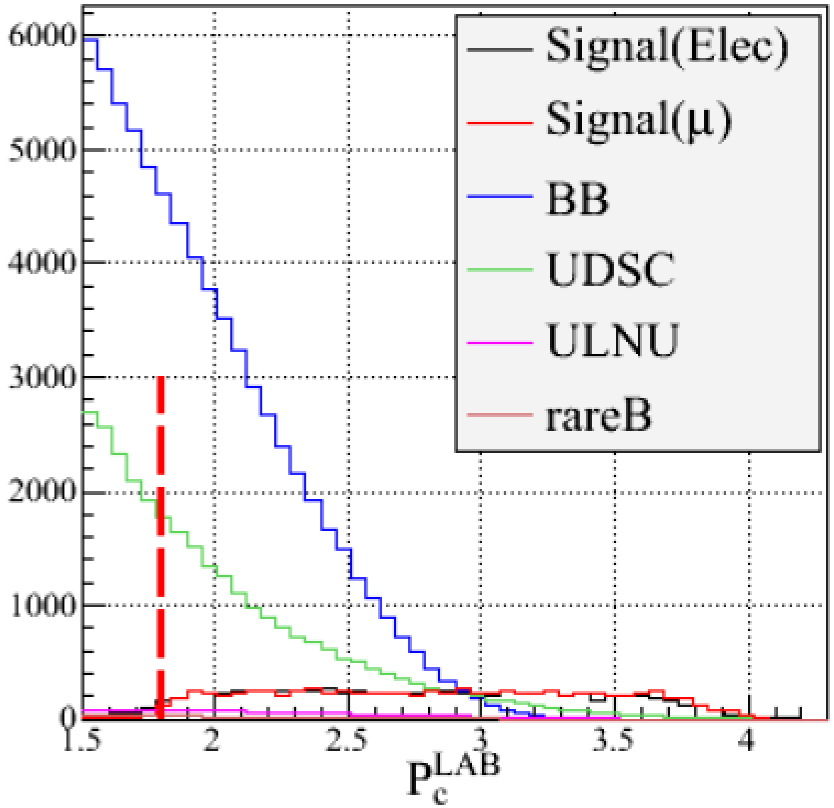
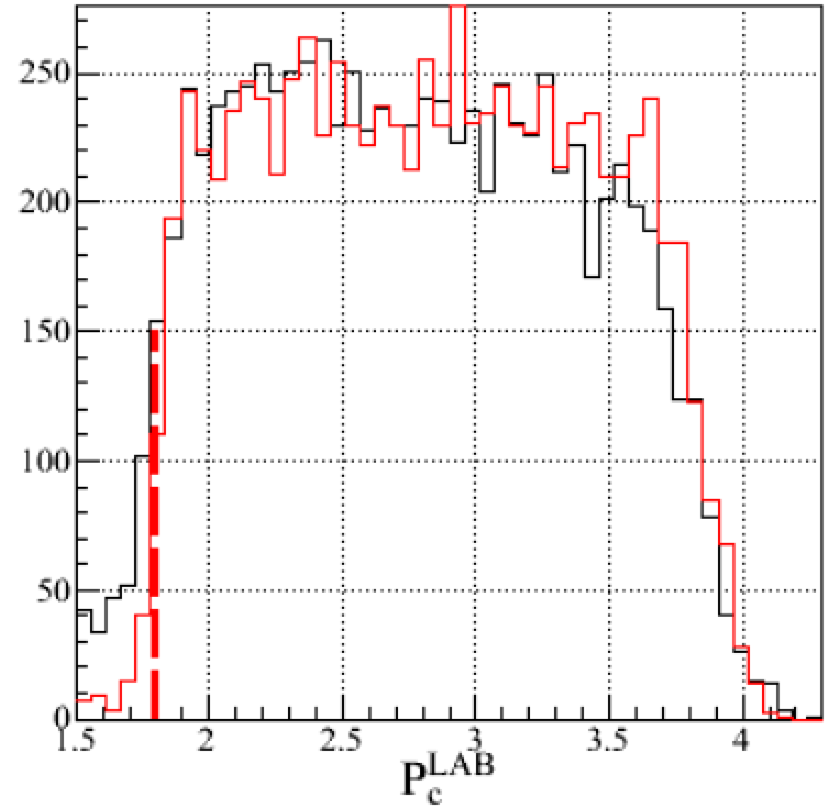


FIG. 19. Purity-efficiency plot for B^+ mesons

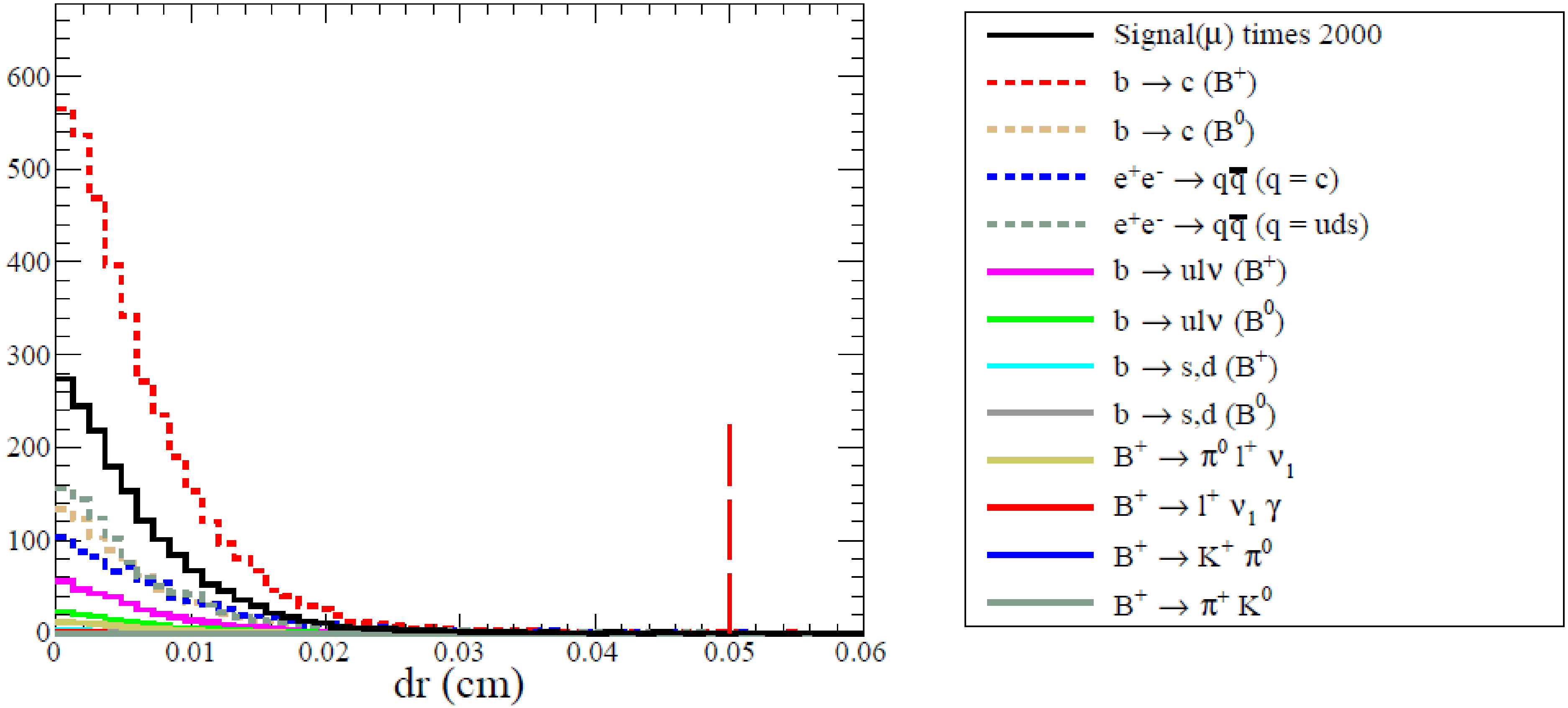
Pre-selection of high mmt tracks

- Pre-selection condition.
- Actually for the file size management.



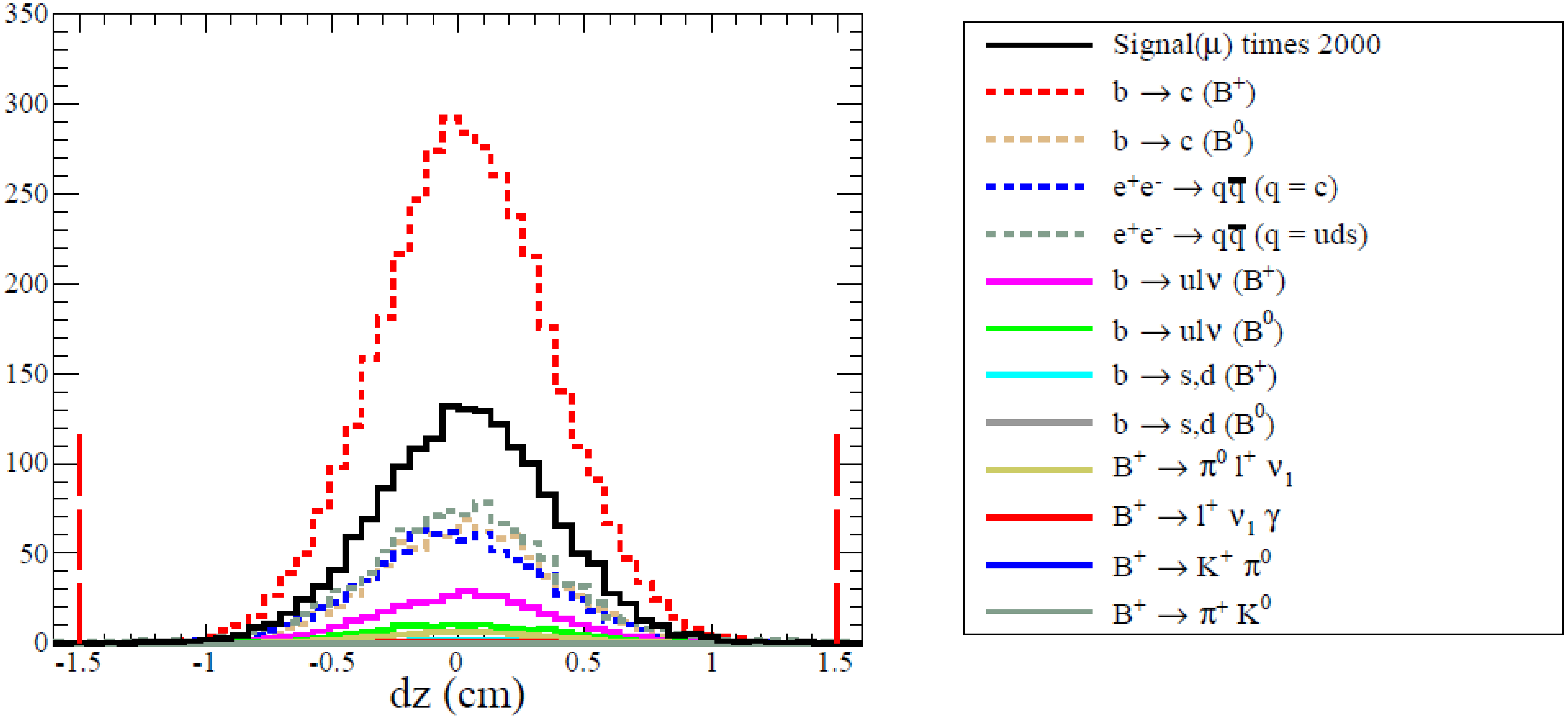


dr distribution



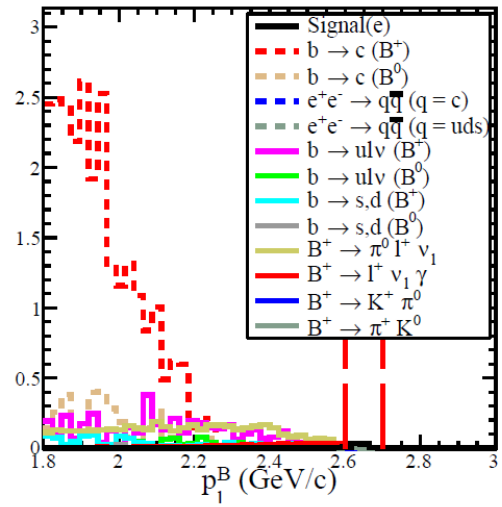
Muon mode. Nearly identical distribution for the electron mode.

dz distribution

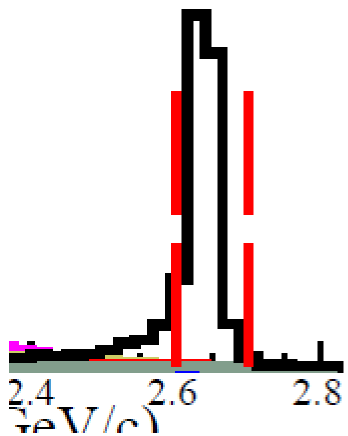


Muon mode. Nearly identical distribution for the electron mode.

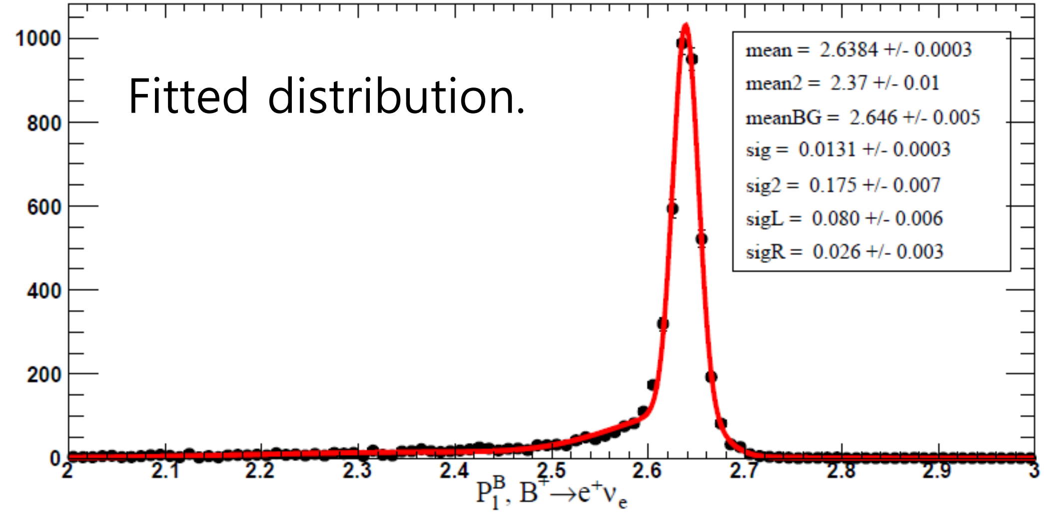
Electron mode p_ℓ^B distribution



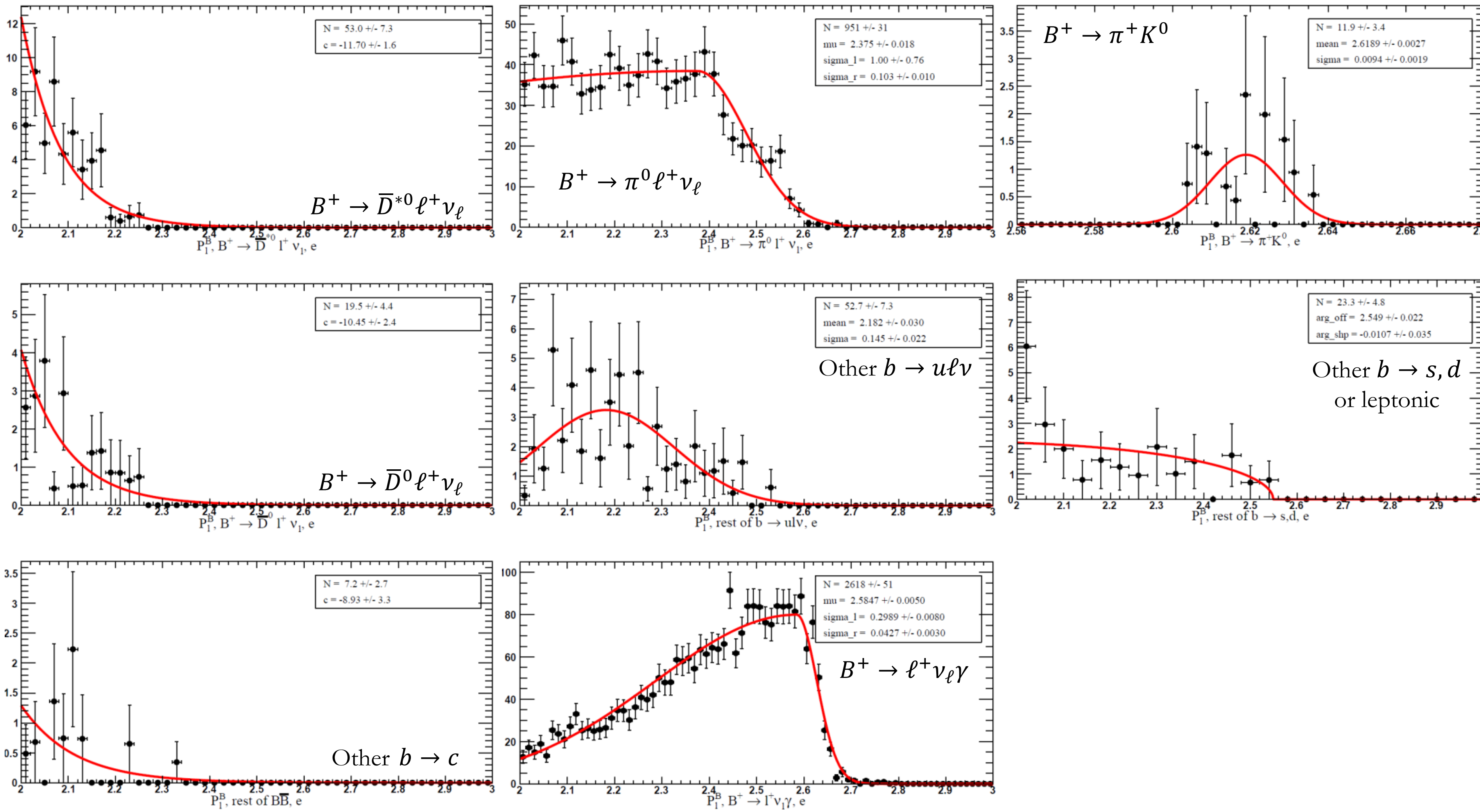
Signal enhanced plot for the electron mode.



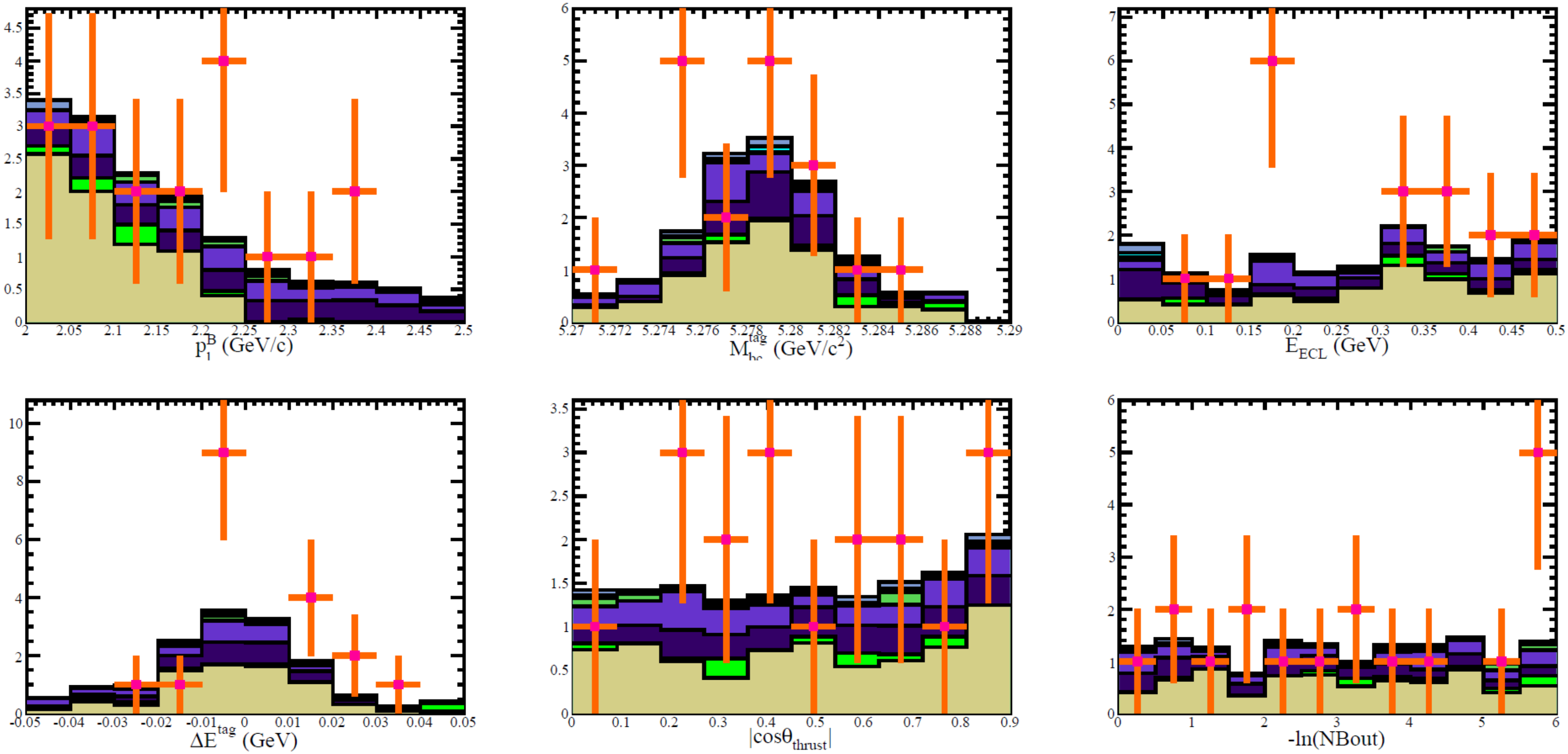
Magnified



Background PDF's for e-mode



Sideband comparison: e-mode



$$\Sigma\ \chi^2/\text{n.d.f.} = 0.39$$

Control sample study: Kpi + K(3pi) mode

```
*************************************** ALL MODES COMBINED *****************************************

Cshape             :  0.9542 (+/- MC:) 0.0065 / 0.0066 (+/- DAT:) 0.0318 / 0.0302 (+/- KPI:) 0.0053 / 0.0052
Cshape comb        :  0.9542 (+/-) 0.0328874 / 0.0313471

****************************************************************************************************

no calib Nsig      :  192.793 (+/- MC:) 5.057 / 5.053 (+/- KPI:) 6.442 / 6.44 (+/- TAG:) 8.09731 / 8.09731 (+/- TRK:) 0.674776 / 0.674776
no calib Nsig comb :  192.793 (+/-) 11.5367 / 11.5338

****************************************************************************************************

no calib Eff       :  0.000434552 (+/- prev:) 2.60034e-05 / 2.59969e-05

****************************************************************************************************

no calib N*e       :  335293 (+/- prev:) 20063.8 / 20058.8 (+/- BB:) 4694.1 / 4694.1
no calib N*e comb  :  335293 (+/-) 20605.6 / 20600.7

****************************************************************************************************
****************************************************************************************************

Nsig               :  183.963 (+/- prev:) 11.0083 / 11.0055 (+/- cal:) 6.34046 / 6.0435
Nsig comb          :  183.963 (+/-) 12.7037 / 12.5557

****************************************************************************************************

Eff                :  0.00041465 (+/-) 2.86339e-05 / 2.83003e-05

****************************************************************************************************

N*e                :  319936 (+/- pre:) 22093.4 / 21836 (+/- bb:) 4479.11 / 4479.11
N*e combined       :  319936 (+/-) 22542.9 / 22290.7

****************************************************************************************************

no calib   BR      :  0.000531908 (+/-) 6.08176e-05 / 6.09299e-05
calibrated BR      :  0.000557438 (+/-) 6.65695e-05 / 6.64285e-05
PDG        BR      :  0.0005752 (+/-) 1.7e-05 / 1.65e-05

****************************************************************************************************
```

N_{bkg}^{MC}

- Calculated as

$$BG_{est} = N_{sideband(Datafitted)} \times \frac{S(MC)_{signal}}{S(MC)_{sideband}}$$

where S/S stands for the rate of events in the signal region to the events in the sideband region.

N_{bkg}^{MC} presented in this talk

- Based on less categorization of BG.
- The uncertainty calculation.
  - Varied the fit parameters by 1σ and summed the effects.
  - The amount of PDG value varied for the well measured modes.
  - Conservative PDG uncertainty assumption for the rest. (+200% -50%, +/- 50% for lnugamma BG).

The uncertainty in S/S of N_{bkg}^{MC}

PDF error	PDF	parameter	$S(MC)_{signal}/S(MC)_{sideband}$
$B\bar{B}$	Exponential	slope	$0.0090^{+0.00048}_{-0.00017}$
		normalization	$0.0090^{+0.00093}_{-0.00076}$
$b \to u\ell\nu$	B.Gaussian	mean	$0.0090^{+0.0023}_{-0.0015}$
		σ(left)	$0.0090^{+0.0019}_{-0.00018}$
		σ(right)	$0.0090^{+0.0034}_{-0.0024}$
		normalization	$0.0090 \pm I.S.$
$RAREB$	Argus	offset	$0.0090 \pm I.S.$
		shape	$0.0090 \pm I.S.$
		normalization	$0.0090 \pm I.S.$
$B \to e\nu\gamma$	B.Gaussian	mean	$0.0090^{+0.00074}_{-0.00075}$
		σ(left)	$0.0090^{+0.00021}_{-0.00017}$
		σ(right)	$0.0090^{+0.00051}_{-0.00053}$
		normalization	0.0090 ± 0.00020
$B^+ \to \pi^+ K^0$	Gaussian	mean	$0.0090 \pm I.S.$
		σ	$0.0090 \pm I.S.$
		normalization	0.0090 ± 0.00079
TOTAL(PDF uncertainty)			$0.0090^{+0.0048}_{-0.0032}$
PDG error			$S(MC)_{signal}/S(MC)_{sideband}$
$B\bar{B}$			$0.0090^{+0.0035}_{-0.0032}$
$b \to u\ell\nu$			$0.0090^{+0.00056}_{-0.00047}$
$RAREB$			$0.0090^{+0.00015}_{-0.00028}$
$B \to e\nu\gamma$			$0.0090^{+0.0014}_{-0.0015}$
$B^+ \to \pi^+ K^0$			$0.0090 \pm I.S.$
TOTAL(PDG uncertainty)			$0.0090^{+0.0039}_{-0.0035}$
GRAND TOTAL			$0.0090^{+0.0061}_{-0.0048}$

$B \to e\nu$

PDF error	PDF	parameter	$S(MC)_{signal}/S(MC)_{sideband}$
$B\bar{B}$	Exponential	slope	$0.012^{+0.00023}_{-0.00014}$
		normalization	$0.012^{+0.0012}_{-0.00098}$
$b \to u\ell\nu$	B.Gaussian	mean	$0.012^{+0.00088}_{-0.00074}$
		σ	$0.012^{+0.0014}_{-0.0012}$
		normalization	$0.012 \pm I.S.$
$RAREB$	Argus	offset	$0.012^{+0.00041}_{-0.00015}$
		shape	$0.012 \pm I.S.$
		normalization	$0.012 \pm I.S.$
$B \to \mu\nu\gamma$	B.Gaussian	mean	0.012 ± 0.00044
		σ(left)	$0.012^{+0.0018}_{-0.00068}$
		σ(right)	$0.012^{+0.00028}_{-0.00030}$
		normalization	$0.012^{+0.00020}_{-0.00020}$
$B^+ \to \pi^+ K^0$	Gaussian1	mean	$0.012^{+0.00036}_{-0.00043}$
		σ	$0.012^{+0.00023}_{-0.00018}$
	Gaussian2	mean	$0.012 \pm I.S.$
		σ	$0.012 \pm I.S.$
		normalization	0.012 ± 0.00097
$B^+ \to K^+ \pi^0$	Gaussian	mean	$0.012^{+0.00014}_{-0.00015}$
		σ	$0.012 \pm I.S.$
		normalization	0.012 ± 0.00019
TOTAL(PDF uncertainty)			$0.012^{+0.0030}_{-0.0022}$
PDG error			$S(MC)_{signal}/S(MC)_{sideband}$
$B\bar{B}$			$0.012^{+0.0058}_{-0.0047}$
$b \to u\ell\nu$			$0.012 \pm I.S.$
$RAREB$			$0.012^{+0.00015}_{-0.00028}$
$B \to \mu\nu\gamma$			0.012 ± 0.0015
$B^+ \to \pi^+ K^0$			0.012 ± 0.00019
$B^+ \to K^+ \pi^0$			$0.012 \pm I.S.$
TOTAL(PDG uncertainty)			$0.012^{+0.0060}_{-0.0050}$
GRAND TOTAL			$0.012^{+0.0067}_{-0.0054}$

$B \to \mu\nu$

The uncertainty in $N_{sideband}$ of N_{bkg}^{MC}

Stat Uncertainty	Data Statistic	13.52 ± 3.61
PDG Uncertainty	$B\bar{B}$	$13.52^{+0.16}_{-0.17}$
	$b \to u\ell\nu$	$13.52^{+0.056}_{-0.066}$
	$RAREB$	$13.52^{+0.0012}_{-0.0007}$
	$B \to e\nu\gamma$	$13.52^{+0.071}_{-0.069}$
	$B^+ \to \pi^+ K^0$	13.52 ± -0.0009
	TOTAL	$13.52^{+0.18}_{-0.20}$
GRAND TOTAL		$13.52^{+3.61}_{-3.62}$

$B \to e\nu$

Stat Uncertainty	Data Statistic	22.09 ± 4.60
PDG Uncertainty	$B\bar{B}$	$22.09^{+0.33}_{-0.39}$
	$b \to u\ell\nu$	$22.09^{+0.071}_{-0.093}$
	$RAREB$	$22.09^{+0.025}_{-0.047}$
	$B \to e\nu\gamma$	22.09 ± 0.11
	$B^+ \to \pi^+ K^0$	$22.09^{+0.0057}_{-0.0058}$
	$B^+ \to K^+ \pi^0$	22.09 ± 0.0008
	TOTAL	$22.09^{+0.35}_{-0.42}$
GRAND TOTAL		$22.09^{+4.61}_{-4.62}$

$B \to \mu\nu$

E-id / Mu-id

- E-id: Likelihood function of
  - Cluster Energy in the ECL
  - Track mmt in the CDC/SVD
  - dE/dx in the CDC
  - Position/shower shape of the cluster in the ECL
  - Response from the ACC
- Mu-id: hit position/depth penetrated at the KLM