# Impact of PID Performance on Physics Reach

**Shohei NISHIDA**

KEK (Belle)

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## Introduction

- PID plays an important role in $B$ factory experiment.
- $K/\pi$ separation is especially crucial.

Examples:

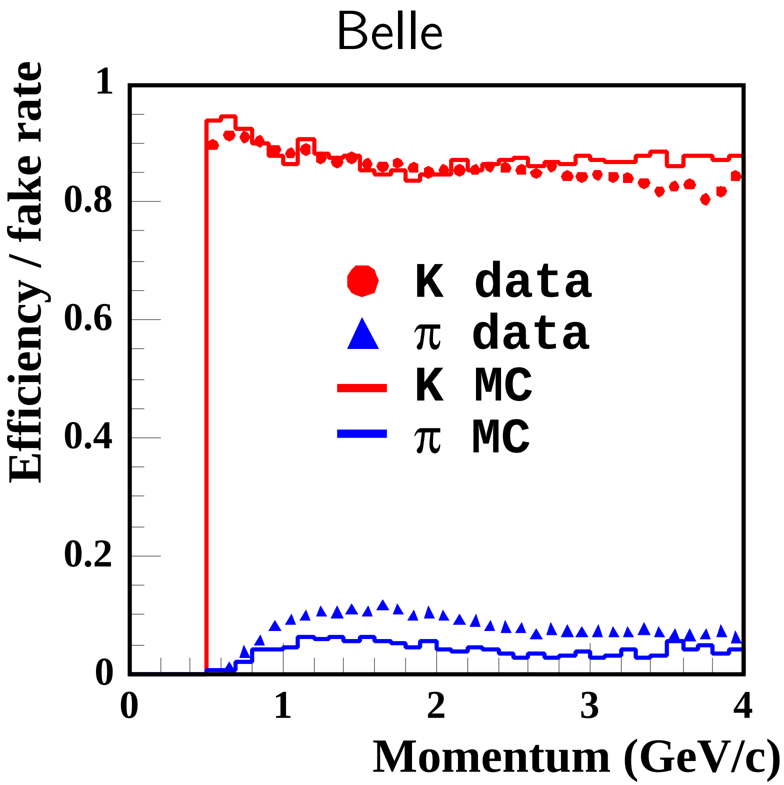
- Flavor tagging in any type of time dependent $CP$ asymmetry measurement.
- 2-body decays: $B \to KK$, $K\pi$, $\pi\pi$.
- $B \to DK$, $B \to D\pi$.
- $B \to K^*\gamma$, $B \to \rho\gamma$.

# *Present $K/\pi$ separation*

## Present KID separation

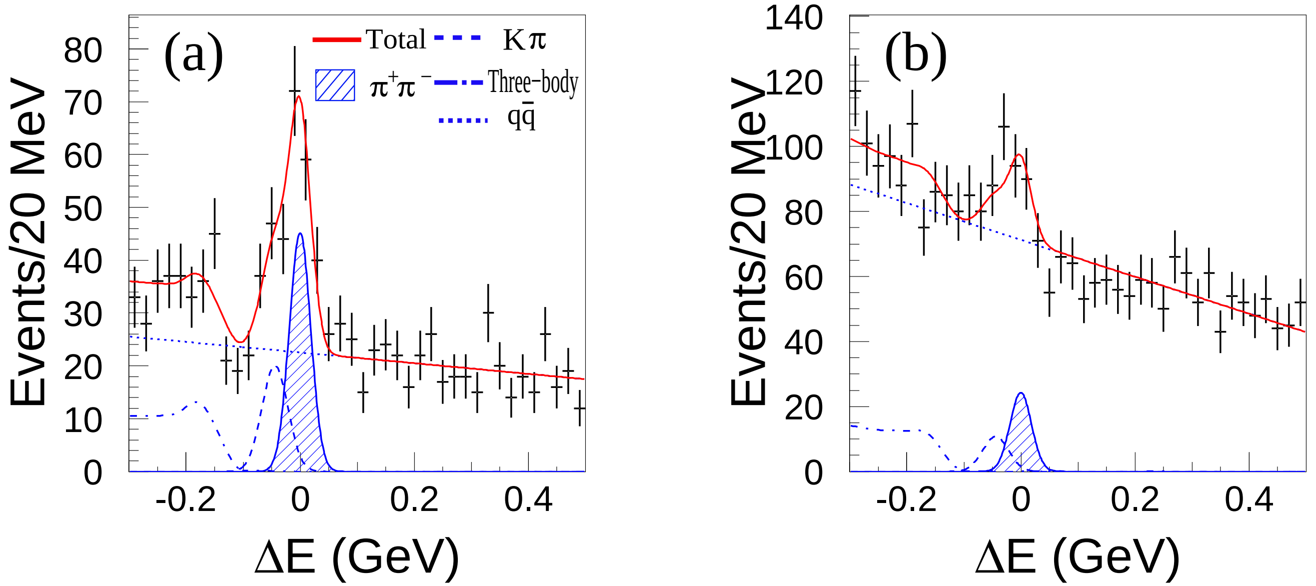
- Present KID system works well both for Belle and BaBar.
- In Belle, CDC + ACC + TOF.
- Roughly $85\%$ efficiency for $K$, $10\%$ $\pi \to K$ fake rate. Similarly for $\pi$ efficiency / $K \to \pi$ fake rate.
- BaBar PID separation is better.

| | $K$ eff. | $\pi \to K$ fake |
|---|---|---|
| Belle $\sim 2$ GeV$/c^2$ | $\sim 85\%$ | $\sim 10\%$ |
| BaBar $\sim 2$ GeV$/c^2$ | $\sim 99\%$ | $\sim 2\%$ |
| B elle $\sim 3$ GeV$/c^2$ | $\sim 83\%$ | $\sim 7\%$ |
| BaBar $\sim 3$ GeV$/c^2$ | $\sim 87\%$ | $\sim 11\%$ |



# $B^0 \to \pi^+\pi^-$

## Example: $B^0 \to \pi^+\pi^-$

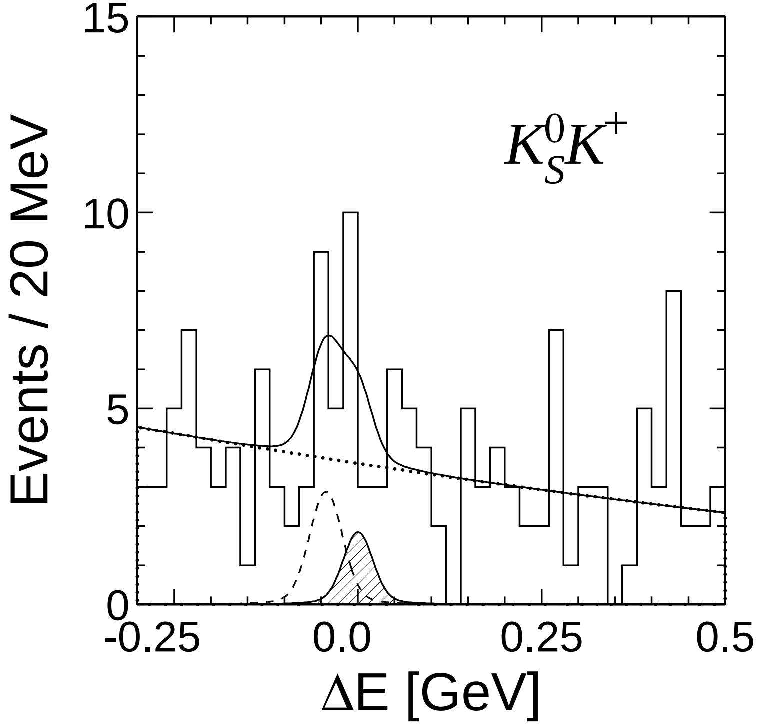



- $\mathcal{B}(B^0 \to K^+\pi^-) = (1.85 \pm 0.12) \times 10^{-5}$
- $\mathcal{B}(B^0 \to \pi^+\pi^-) = (4.8 \pm 0.5) \times 10^{-6}$
- Thanks to the PID, $K^+\pi^-$ component is reasonably small.
- It would be nice if we can suppress $K^+\pi^-$ more (another factor of $2 \sim 5$).

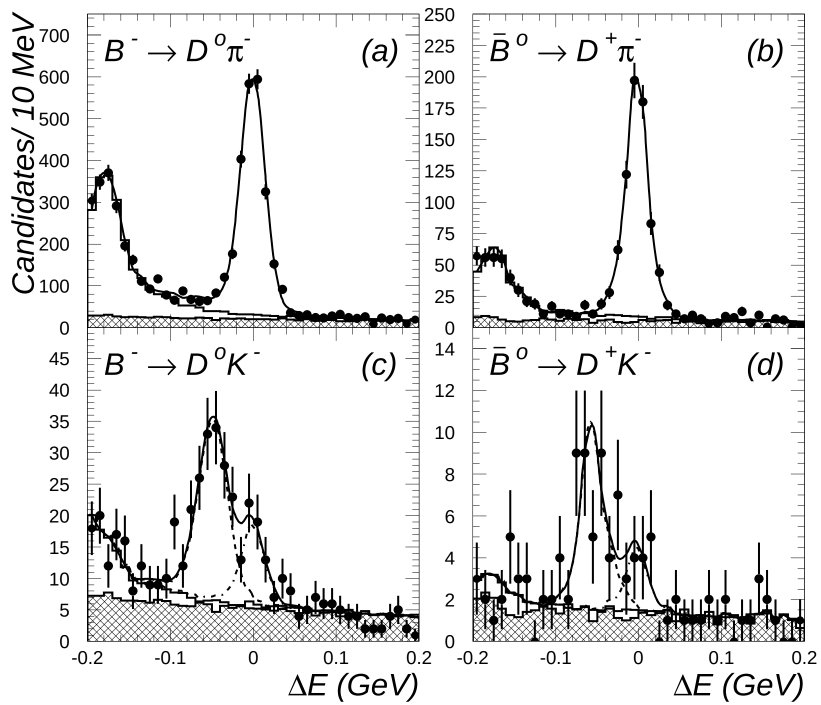
# $B \to KK,\ DK$

## Example: $B \to KK,\ DK$

$B^+ \to K_S K^+$




$B \to DK$

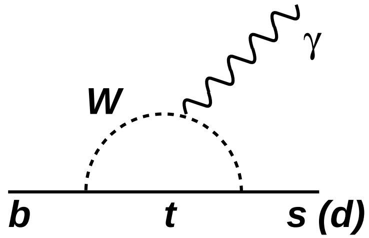



- $\pi \to K$ fake rate improvement will help these analysis.
- $\Delta E$ shift (due to different mass hypothesis) can also be used for $K/\pi$ separation.

# $B \to \rho\gamma$ *against* $B \to K^*\gamma$

## $B \to \rho\gamma$ against $B \to K^*\gamma$

$$\frac{\mathcal{B}(B^+ \to \rho^+\gamma)}{\mathcal{B}(B^+ \to K^*\gamma)} = \left|\frac{V_{td}}{V_{ts}}\right|^2 \left(\frac{1 - m_\rho^2/M_B^2}{1 - m_{K^*}^2/M_B^2}\right) \xi^2 (1 + \Delta R),$$




where $\xi \sim 0.76 \pm 0.06$, $\Delta R < 0.15$.

- Measurement of $|V_{td}|$.
- Direct $CP$ Violation can be large in the SM.
- Time dependent asymmetry of $B^0 \to \rho^0\gamma$ is expected to be small in the SM, but can be large in the non-SM model $\Longrightarrow$ sensitive probe for New Physics

Prediction [A.Ali and P.Y.Parkhomenko, Euro. Phys. J. C23, 89 (2002)]

$$\mathcal{B}(B^+ \to \rho^+\gamma) = (0.85 \pm 0.30 \pm 0.10) \times 10^{-6} \quad (1)$$
$$\mathcal{B}(B^0 \to \rho^0\gamma) = (0.49 \pm 0.17 \pm 0.04) \times 10^{-6} \quad (2)$$

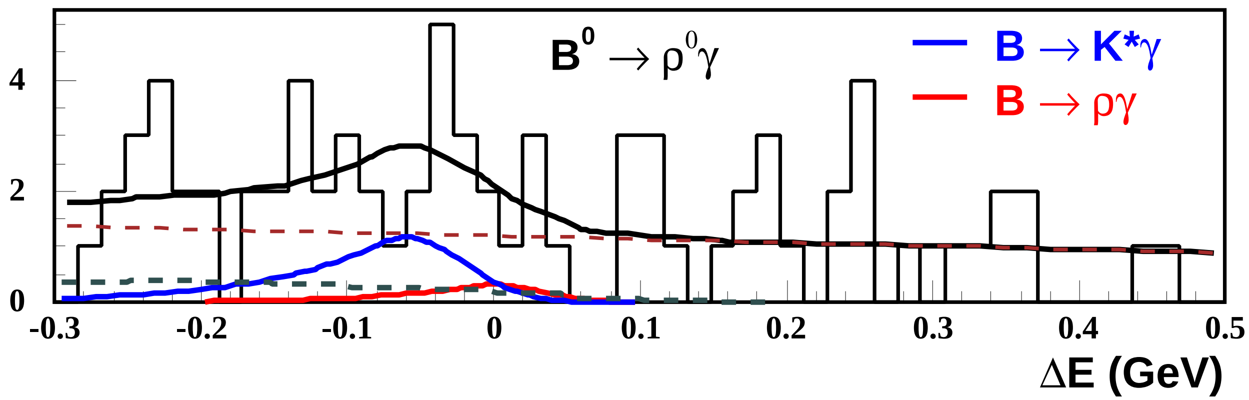
c.f.) $\mathcal{B}(B \to K^*\gamma) \sim 4 \times 10^{-4}$

## $B \to \rho\gamma$ against $B \to K^*\gamma$

Present status

$$\mathcal{B}(B^+ \to \rho^+\gamma) < 2.1 \times 10^{-6} \quad \text{(BaBar)}$$
$$< 2.6 \times 10^{-6} \quad \text{(Belle)}$$
$$\mathcal{B}(B^0 \to \rho^0\gamma) < 1.2 \times 10^{-6} \quad \text{(BaBar)}$$
$$< 2.7 \times 10^{-6} \quad \text{(Belle)}$$

Belle $\rho^0\gamma$



# $B \to \rho\gamma$ *against* $B \to K^*\gamma$

## $B \to \rho\gamma$ at $50\ \mathrm{ab}^{-1}$

Simple study with signal MC.

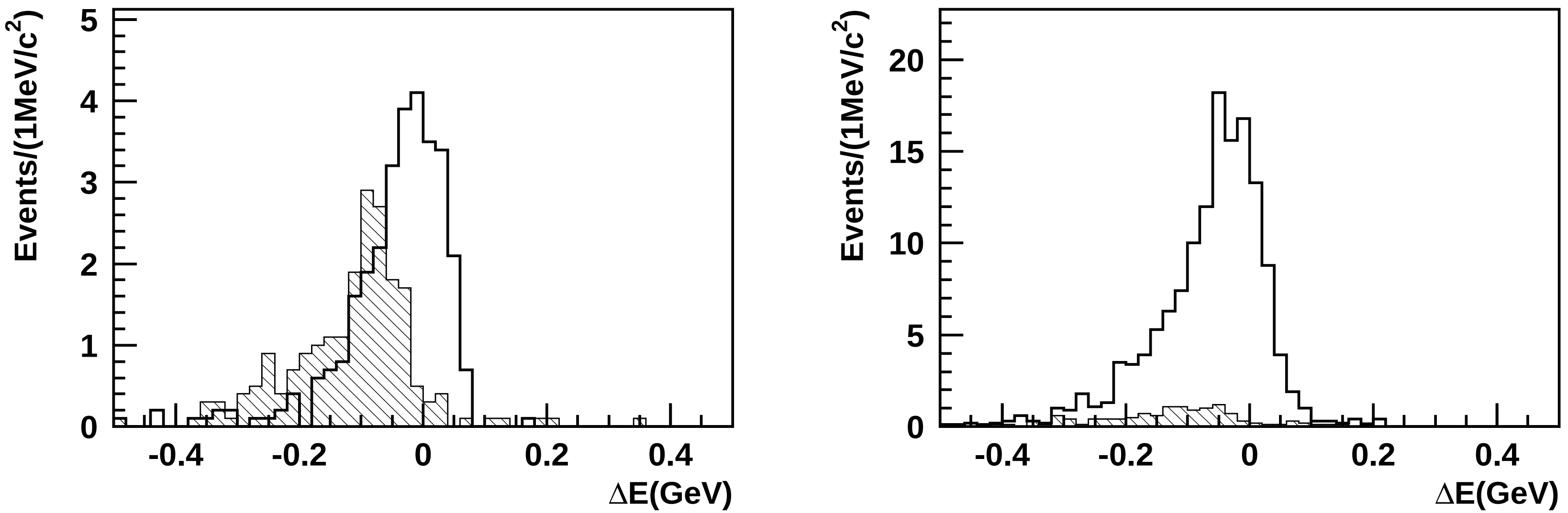
- $|M(\pi\pi) - M_\rho| < 200\ \mathrm{MeV}/c^2$
- $|M(K\pi) - M_{K^*}| > 80\ \mathrm{MeV}/c^2$
- $\pi^0/\eta$ veto, $+\ 10\%$ efficiency for continuum suppression
- PID: $90\%$ $\pi$ efficiency
- $K \to \pi$ mis-identification rate is varied

where $M(K\pi)$ is the invariant mass of $\pi\pi$ assuming kaon mass for the higher momentum $\pi$.

## $B \to \rho\gamma$ against $B \to K^*\gamma$

Assuming $3\%$ $K \to \pi$ mis-identification rate:

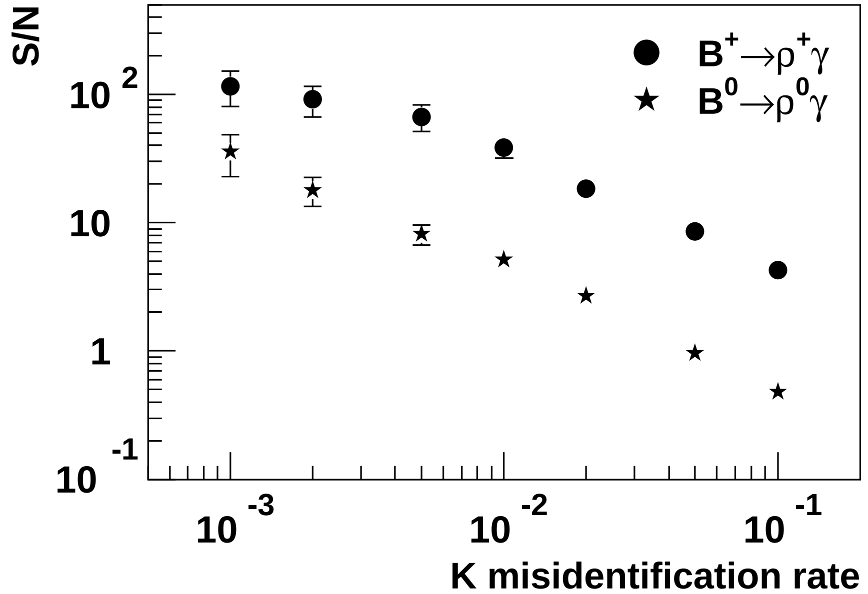
$B^0 \to \rho^0\gamma$ ($\sim 30$ evts) $B^+ \to \rho^+\gamma$ ($\sim 130$ evts)




- $\Delta E$ shift is not enough to separate $B \to \rho\gamma$ and $B \to K^*\gamma$ due to energy leakage at the calorimeter for photons.
- $B \to K^*\gamma$ contribution for charged mode is reasonably small (due to large $\rho\gamma$ BF and small $K^{*0}\gamma \to K^+\pi^0\gamma$ BF)
- Severe $B \to K^*\gamma$ background for neutral mode. We can still decrease it by tighter selections, but we loose statistics.

## $B \to \rho\gamma$ *against* $B \to K^*\gamma$

$N(\rho\gamma)/N(K^*\gamma)$ v.s. PID

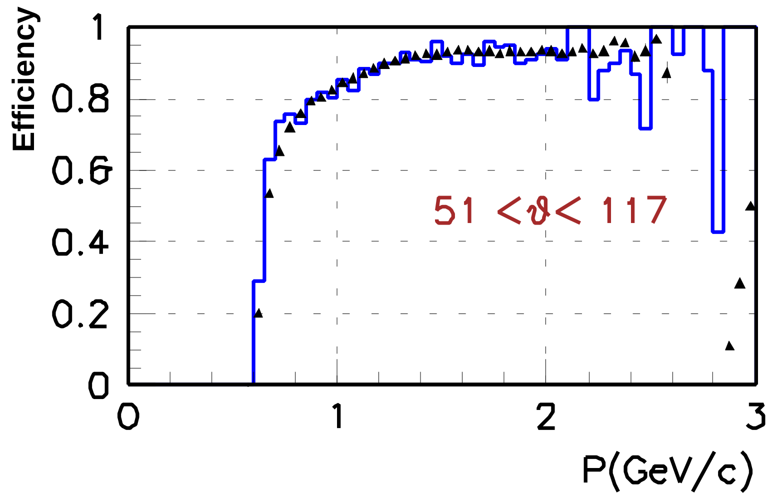



- Mis-identification of around $1\%$ is necessary. i.e. $4\sigma$ separation.

# $\mu/\pi$ *separation for* $b \to s\ell\ell$

$\mu/\pi$ separation for $b \to s\ell\ell$

Present $\mu$ identification

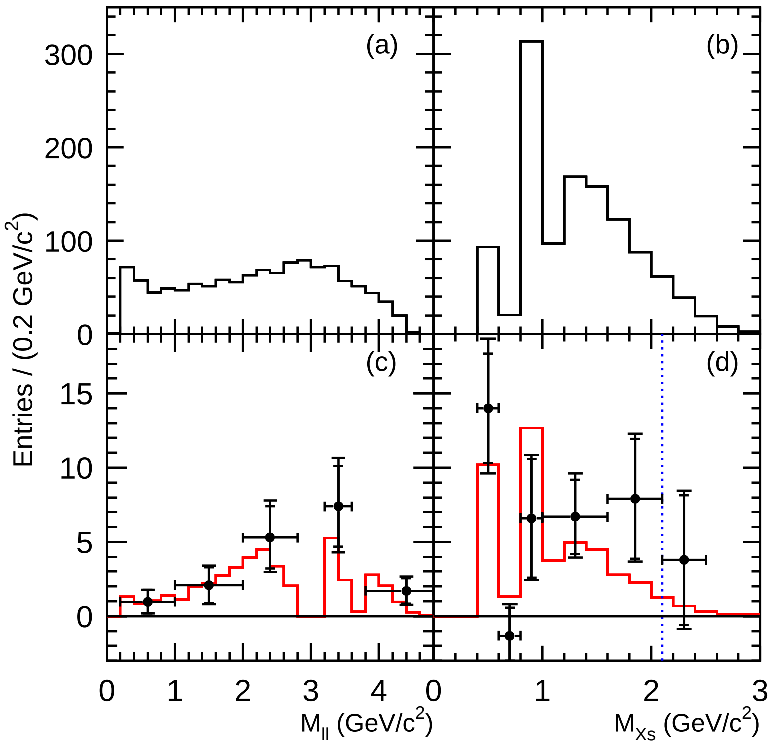



- Muon is identified by the outer muon detector (KLM/IFR).
- We cannot identify $\mu$ below $0.7\ \mathrm{GeV}/c^2$.
- Impact of $\mu$ ID below $0.7\ \mathrm{GeV}/c^2$ to physics ?

# $\mu/\pi$ *separation for* $b \to s\ell\ell$

Example: $b \to s\ell\ell$

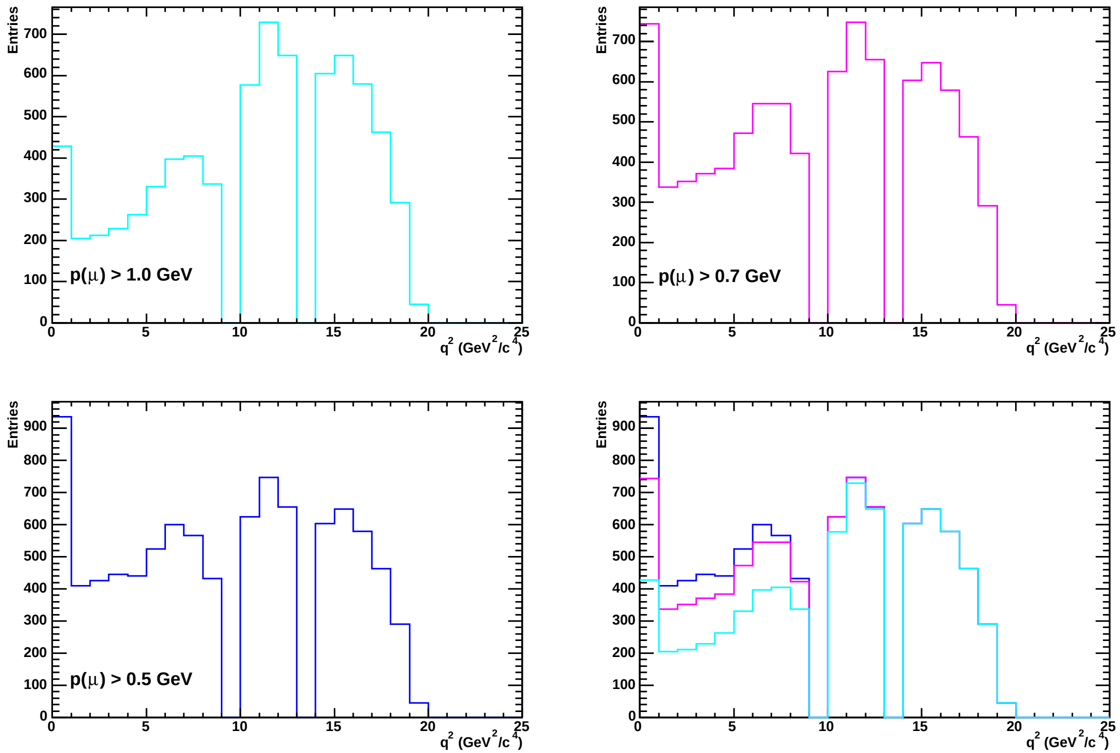
- Sensitive to New Physics.
- Measurement of branching fraction and forward-backward asymmetry.
- $M^2(\ell^+\ell^-) < 3\ \mathrm{GeV}/c^2$ is important.
  ($c\bar{c}$ resonances such as $J/\psi$ causes theoretical uncertaintly)



# $\mu/\pi$ *separation for* $b \to s\ell\ell$

$B^+ \to K^+\ell^+\ell^-$ at $50\ \mathrm{ab}^{-1}$

- Signal MC for $p > 1.0\ \mathrm{GeV}/c^2$, $p > 0.7\ \mathrm{GeV}/c^2$ and $p > 0.5\ \mathrm{GeV}/c^2$
- $\mu$ identification efficiency is assumed to be $90\%$




- Improvement on the efficiency at $M(\ell^+\ell^-) < 3\ \mathrm{GeV}/c^2$.

# *Conclusion*

## Conclusion

- PID (especially $K/\pi$ separation) has been played an crucial role in the present $B$ factories.
- Further imporvement is essential. $4\sigma$ $K/\pi$ separation ($1\%$ fake rate) is desirable.
- $\mu/\pi$ selection at $p < 0.7\ \mathrm{GeV}/c^2$ also has some impact on physics.