Studies of radiative *B* meson decays with Belle

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on behalf of the Belle Collaboration

- Outline -

1. Measurement of Br($b \to s\gamma$)

2. Measurement of Br($B \to K^*\gamma$)

3. Search for $B \to \rho\gamma$

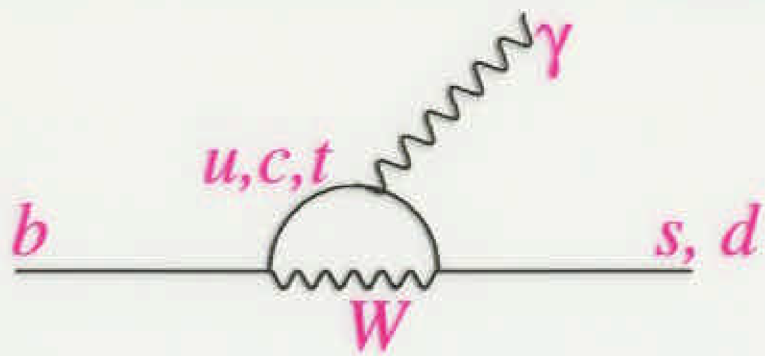
4. Summary

Contribution paper is available as #281 / BELLE-CONF-0003

Radiative B decays

EW penguin

NLO calculation is available for $b \to s\gamma$
Sensitive to non-SM
(charged Higgs, SUSY, ...)



Inclusive measurement - theoretically clear
Exclusive $K^*\gamma$ measurement - experimentally straightforward

$b \to d\gamma$ transition

$|V_{td}/V_{ts}|$ measurement
Direct CP within SM
Possibly better sensitivity to non-SM

⇨ *Will be more interesting with a larger data sample*

Data sample with Belle

5.1 fb^{-1} $B\bar{B}$ data + 0.6 fb^{-1} off-resonance for background subtraction

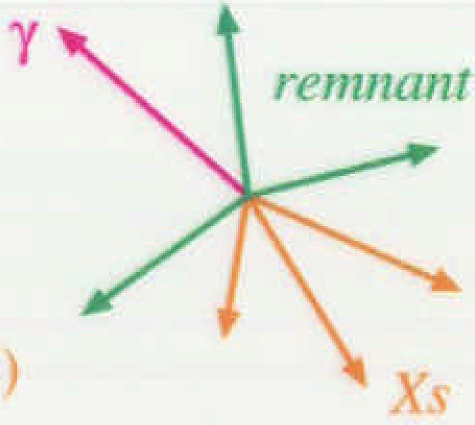
1. Inclusive $b \to s\gamma$ measurement

Analysis

Reconstruction analysis, combining 1 photon + semi-inclusive Xs
[1 $K^{\pm}$ or K_S + 1 to 4 π (up to 1 π^0)] (16 Xs combinations)

Construct $M_B = \sqrt{E_{beam}^2 - |p_B|^2}$ and $\Delta E = E_B - E_{beam}$
Best candidate based on ΔE - *[use M_B for background rej.]*

Background reduction



$E_\gamma > 2.1$ GeV, $M(Xs) < 1.85$ GeV
Barrel CsI only, π^0 / η veto
Loose particle-id: keep 88% kaons and 96% pions
New event shape variable - Super Fox-Wolfram (SFW)

$R_l^{maj} = \Sigma_i |p_i||p_\gamma| P_l(\cos\theta_{i\gamma}) / \Sigma_i |p_i||p_\gamma|$
$R_l^{min} = \Sigma_{i,j} |p_i||p_j| P_l(\cos\theta_{ij}) / \Sigma_i |p_i||p_j|$

⇨ $SFW = \Sigma_{l=1,4} [\, \alpha_l R_l^{maj} + \beta_l R_l^{min} \,]$
(Fisher discriminant)

⇨ New technique to subtract the background using a small off-resonance sample

SFW and background subtraction

2.3σ separation

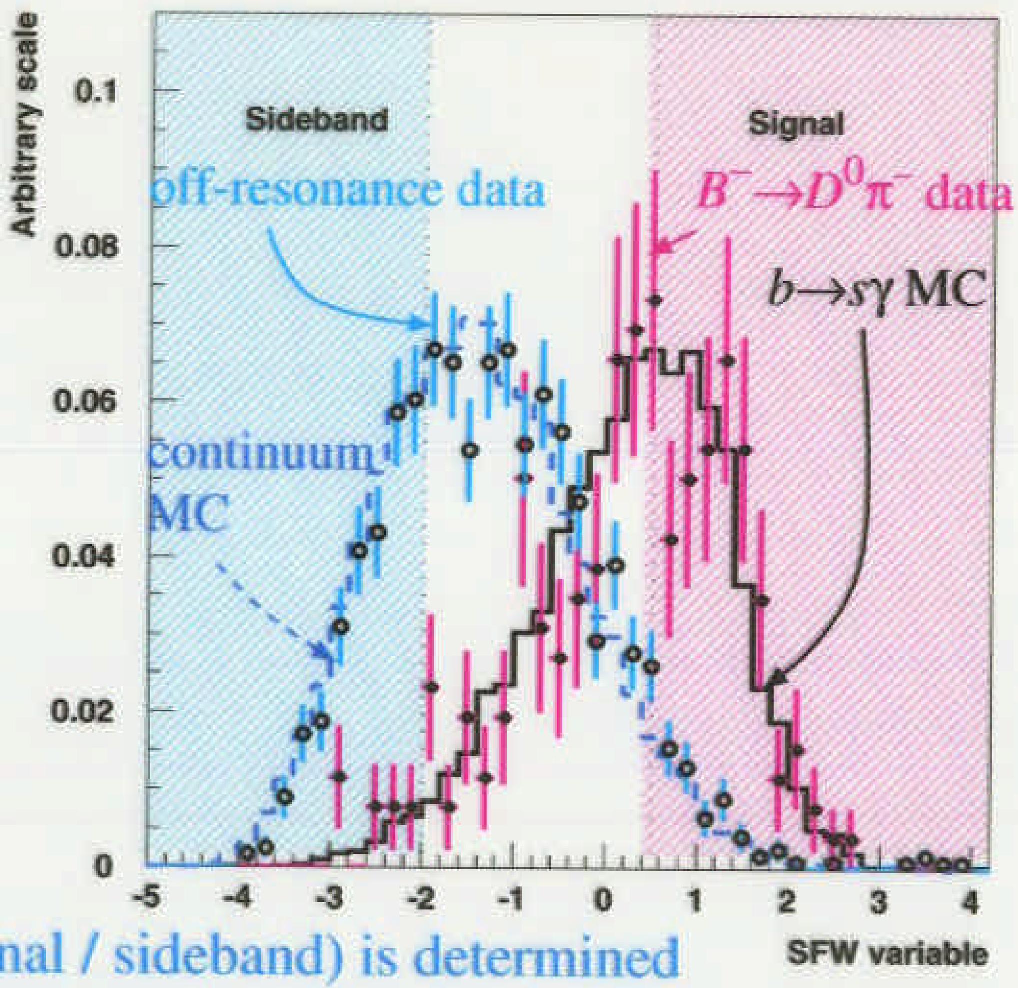
S/N > 1 in signal region: SFW>0.5

No correlation with E_γ nor ΔE
No correlation with M_B,
if γ and *Xs* are back-to-back

⇩

SFW sideband events can be used as the clean background sample to subtract

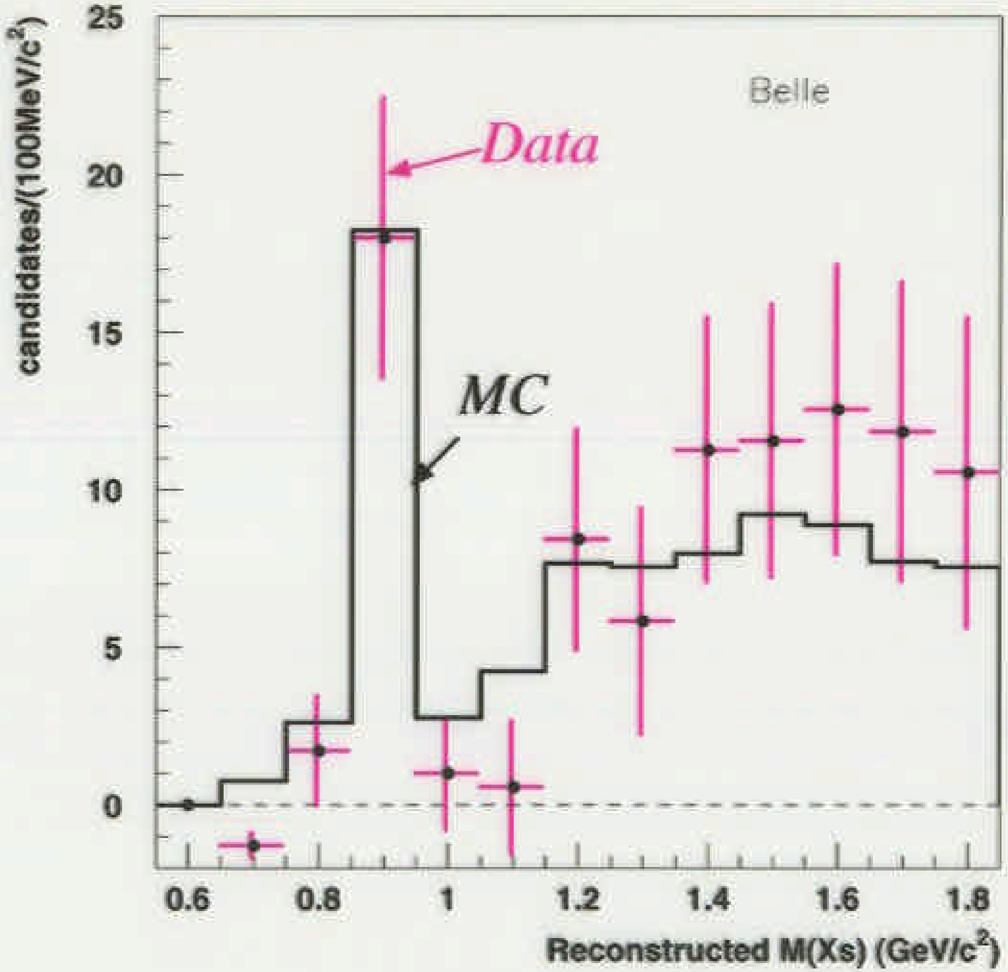
Only ~2% of signal in sideband: SFW<-2



Sideband scaling factor (ratio of signal / sideband) is determined from the off-resonance data. (tiny systematic shift exists in MC)

r ~ 0.14 statistical error ~ 10% systematic error ~ 6%

M(Xs) distribution



Signal MC sample

- $K^*(892)\gamma$ + inclusive $b \to s\gamma$ for M(Xs)>1.1 GeV
- Ali-Greub model for M(Xs), $p_F = 0.3$ GeV, hadronized with JETSET.
- 60% of events are categorized as $1K$+1 to 4π

Systematic errors

Systematic errors in efficiencies - checked with a large statistics data sample.

Photon efficiency	*radiative Bhabha*	*5%*
Tracking efficiency	$\eta \to \pi^+\pi^-\pi^0$ / $\eta \to \gamma\gamma$	*1.4 to 4% (mom. dep.)*
Particle-id efficiency	$\phi \to K^+K^-$	*0.8%*
π^0 efficiencies	$D^0 \to K^-\pi^+\pi^0$ / $D^0 \to K^-\pi^+$	*7%*
K_S efficiencies	$D^0 \to K_S\pi^+\pi^-$ / $D^0 \to K^-\pi^+$	*10%*
SFW and π^0/η veto	$B^- \to D^0\pi^-$; $D^0 \to K^-\pi^+$	*6%*

Systematic errors in signal yield

Yield = $\Sigma\, \varepsilon_{ij} N_j$ (efficiency × population for 16 reconstruction modes)

Errors on ε_{ij} (i=j) are calculated from individual efficiency uncertainties for 16 modes. Errors on ε_{ij} (i≠j) are negligible.

Errors on N_j are evaluated by varying the $M(Xs)$ distribution.

⇨ theoretical error

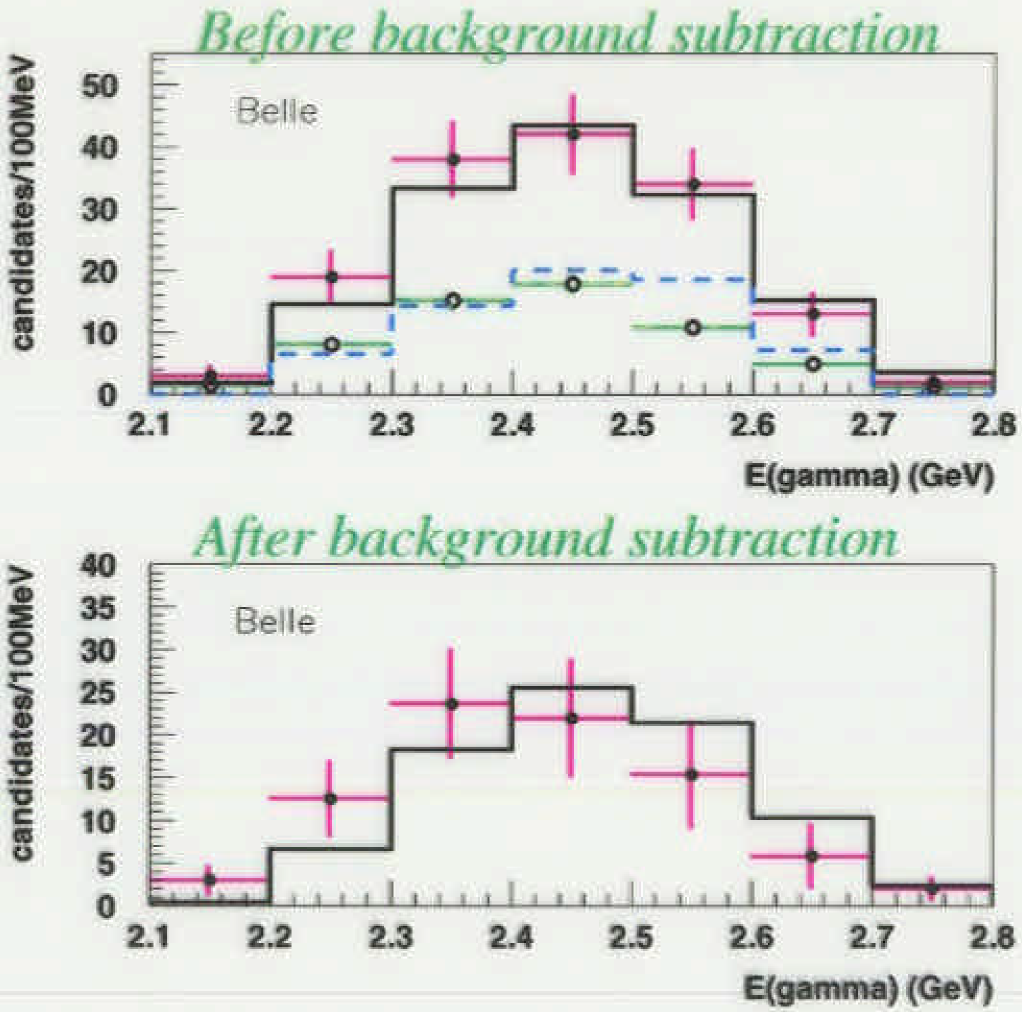
Other error sources

Background scaling factor : 6%, N_{BB}: 1%

Inclusive branching fraction

152 candidates

60 ± 7 background
92 ± 14 signal yield



$$Br = (\,3.34 \pm 0.50\ (\text{stat})\ {}^{+0.34}_{-0.37}\,(\text{syst})\ {}^{+0.26}_{-0.28}\,(\text{theo}))\times 10^{-4}$$

[Belle Preliminary]

2. $B \to K^* \gamma$ measurement

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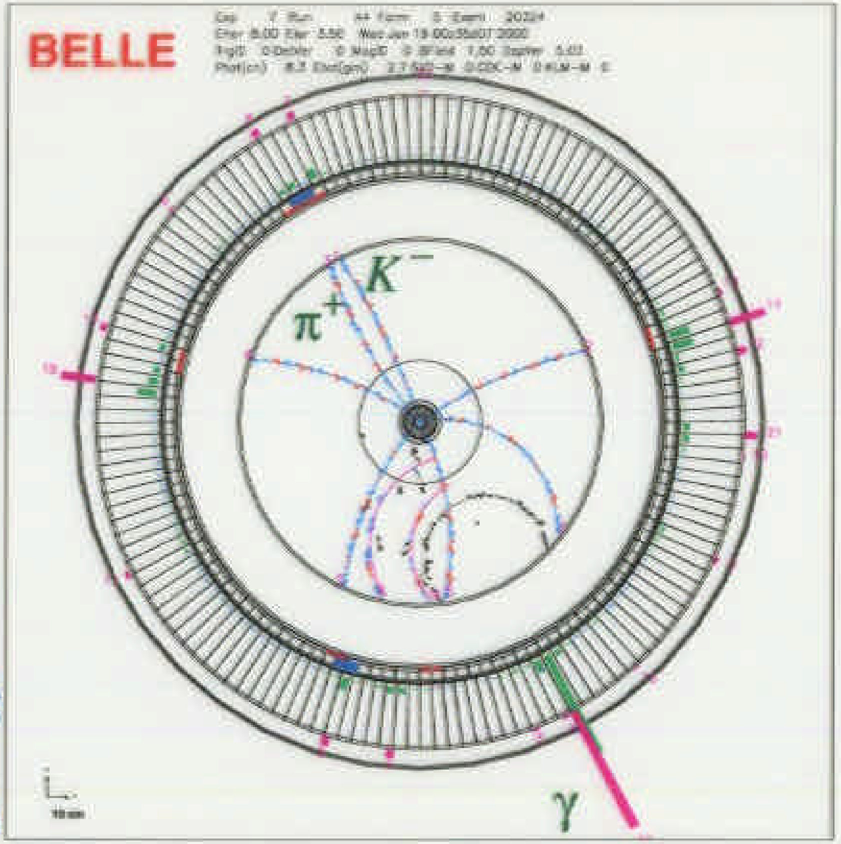
Reconstructed channels

B^0 $K^+\pi^-\gamma$, $K_S\pi^0\gamma$

B^+ $K_S\pi^+\gamma$, $K^+\pi^0\gamma$ (+ c.c.)



Background reduction

Most of the cuts are the same as the inclusive analysis

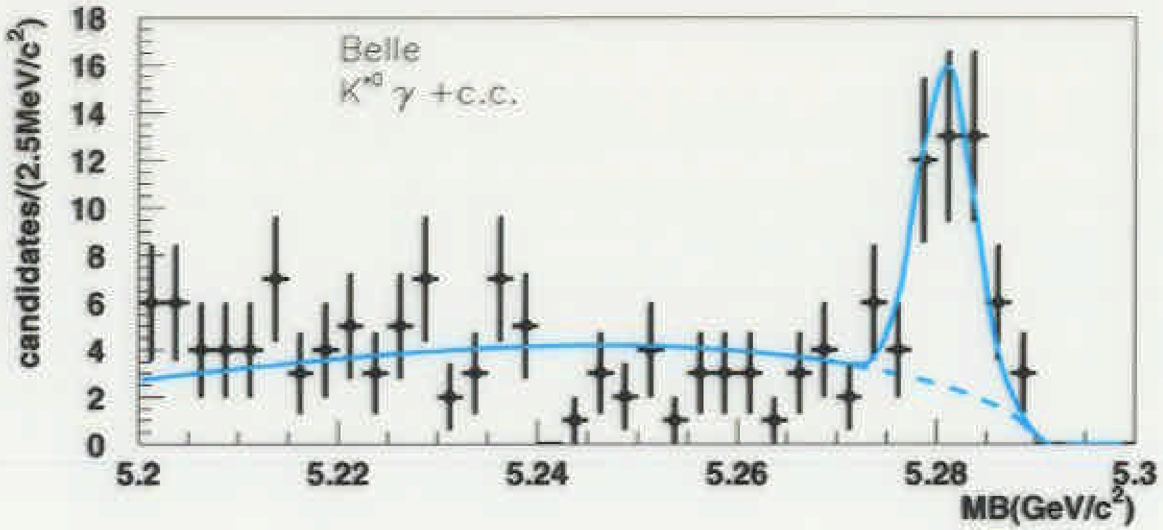
SFW cut is replaced with a likelihood ratio (LR) of 3 variables:

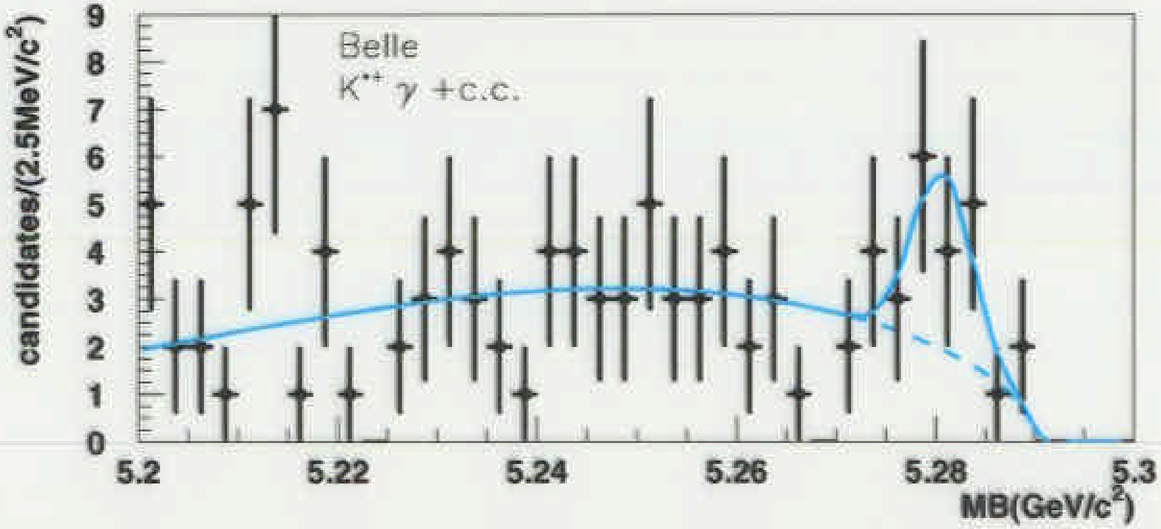
	SFW,	$\cos\theta_B$,	$\cos\theta_H$
signal PDF:	asym.gauss,	$\sin^2\theta_B$,	$\sin^2\theta_H$
continuum:	asym.gauss,	const.,	$a+b\,e^x$

$$L^{sig} = p^{sig}_{SFW} \times p^{sig}_B \times p^{sig}_H$$
$$L^{bg} = p^{bg}_{SFW} \times p^{bg}_B \times p^{bg}_H$$

$$LR = L^{sig} / (L^{sig} + L^{bg})$$

Make a cut to keep 65%





Results

$B^0 \rightarrow K^{*0}\gamma$

signal yield $33.7 \pm 6.9\,^{+6.8}_{-1.4}$

$Br = (4.94 \pm 0.93^{+0.55}_{-0.52}) \times 10^{-5}$

[Belle Preliminary]

$B^+ \rightarrow K^{*+}\gamma$

signal yield $8.7 \pm 4.2\,^{+2.8}_{-0.4}$

$Br = (2.87 \pm 1.20^{+0.55}_{-0.40}) \times 10^{-5}$

[Belle Preliminary]

Systematic errors:

Efficiencies	*8 to 10%*
LR cut	*6%*
Fitting	*5 to 15%*

3. *Search for* $B \to \rho\gamma$

Reconstructed channels

B^0: $\pi^+\pi^-\gamma$ B^+: $\pi^+\pi^0\gamma$

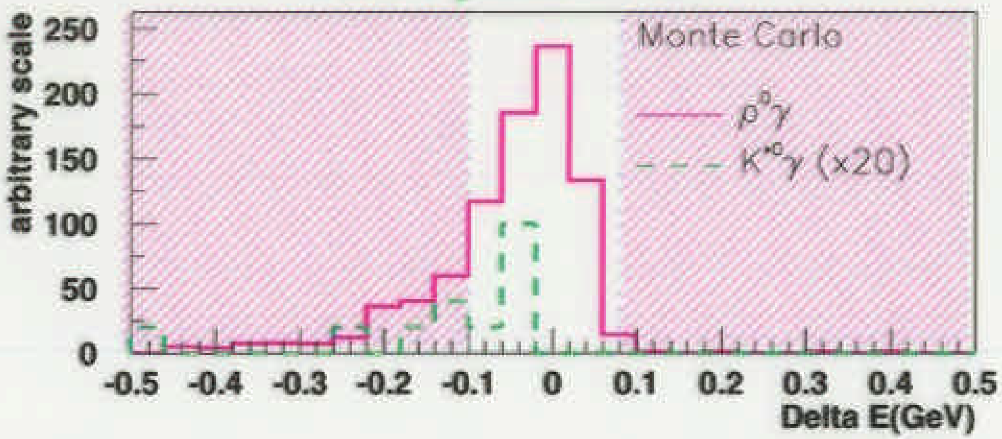
Analysis

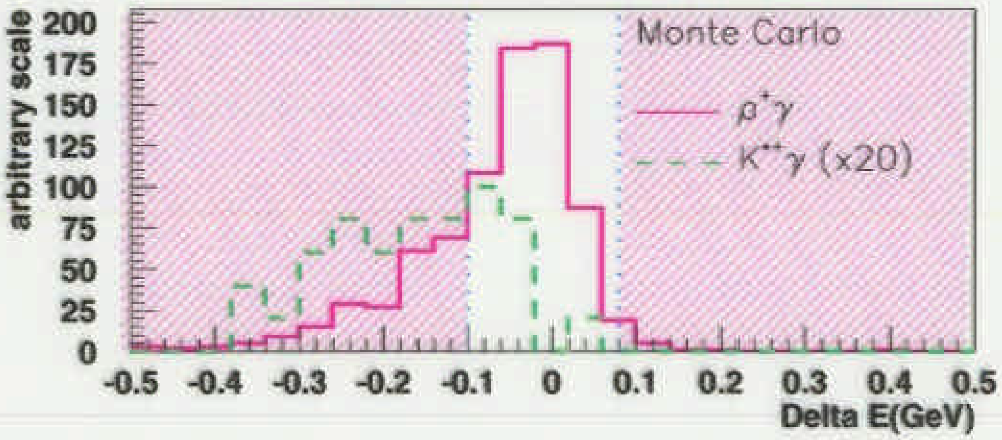
Variant of $K^*\gamma$ analysis
Tighten particle-id,
rejecting 80% kaons

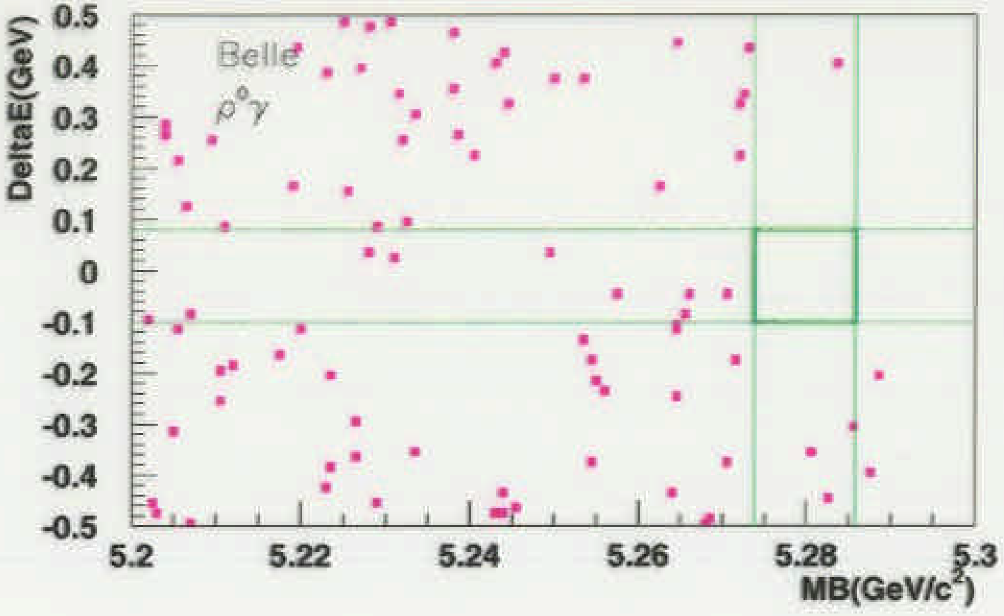
$K^*(892)$ veto for B^0 analysis
Tighten LR cut (keep 40%)

Feed down from $K^*\gamma$ is
not a serious problem
– *negligible at this moment.*

After particle ID





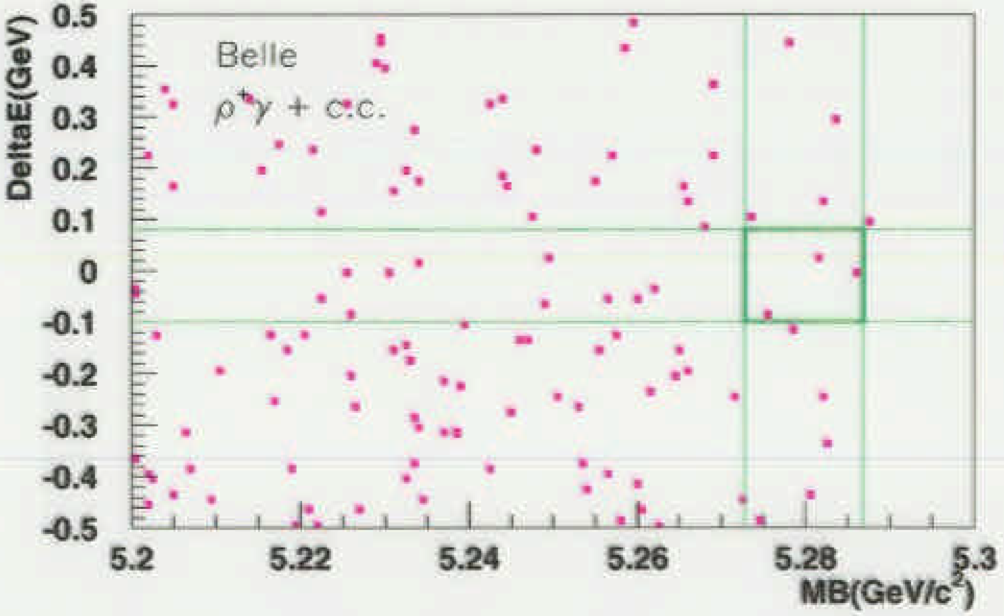


$\pi^+\pi^-\gamma$

0 event in 2σ signal window

$Br(B^0 \to \rho^0\gamma) < 0.56 \times 10^{-5}$ (90% C.L.)

[Belle Preliminary]



$\pi^+\pi^0\gamma$

3 events in 2σ signal window

$Br(B^+ \to \rho^+\gamma) < 2.27 \times 10^{-5}$ (90% C.L.)

[Belle Preliminary]

Ratio

$Br(B \to \rho\gamma) / Br(B \to K^*\gamma) < 0.28$

(90% C.L.)

[Belle Preliminary]

Using $K^*\gamma$ result with the same tight LR cut to cancel systematics

4. Summary

First preliminary results from Belle are reported.

$Br\,(b\to s\gamma) = (\,3.34 \pm 0.50\,^{+0.34}_{-0.37}\,^{+0.26}_{-0.28}\,)\times 10^{-4}$

$Br(B^0\to K^{*0}\gamma) = (4.94\pm 0.93^{+0.55}_{-0.52})\times 10^{-5}$

$Br(B^+\to K^{*+}\gamma) = (2.87\pm 1.20^{+0.55}_{-0.40})\times 10^{-5}$

$B\to\rho\gamma$ is searched and new limits are given

$Br(B^0\to\rho^0\gamma) < 0.56\times 10^{-5}$ (90% C.L.)

$Br(B\to\rho\gamma)\,/\,Br(B\to K^*\gamma) < 0.28$ (90% C.L.)

Results will be quickly improved in the coming runs.