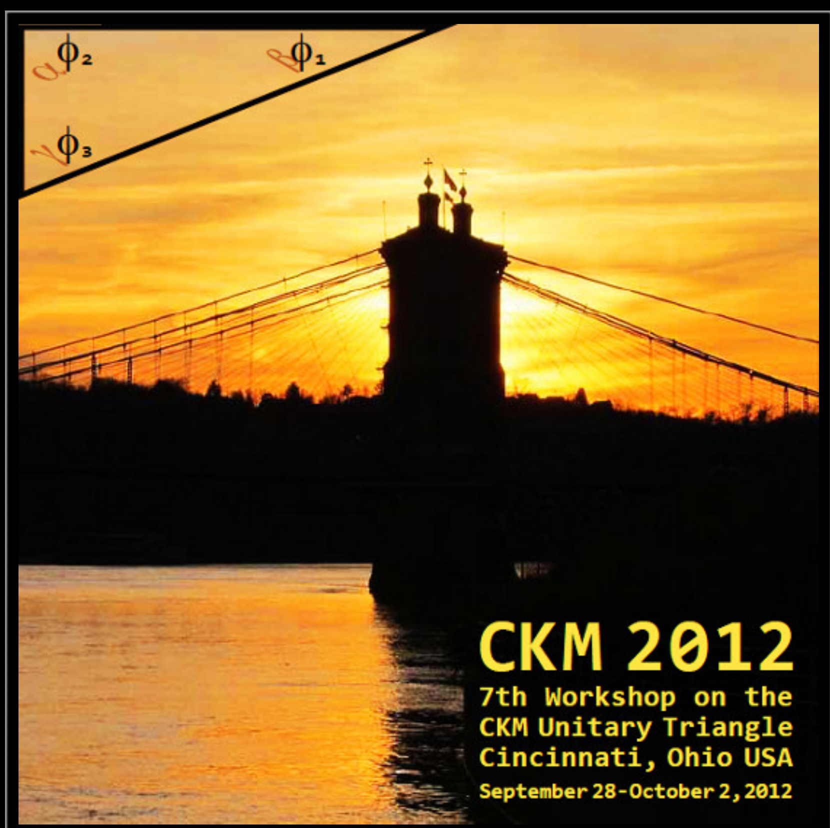

YONSEI UNIVERSITY

BELLE

$b \to s\gamma$ result from Belle

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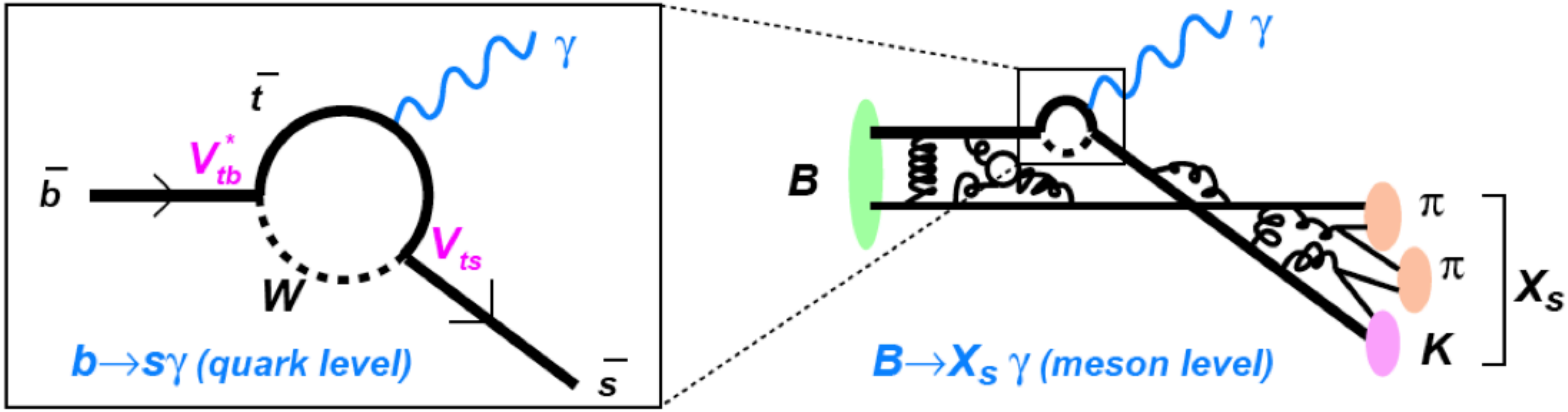
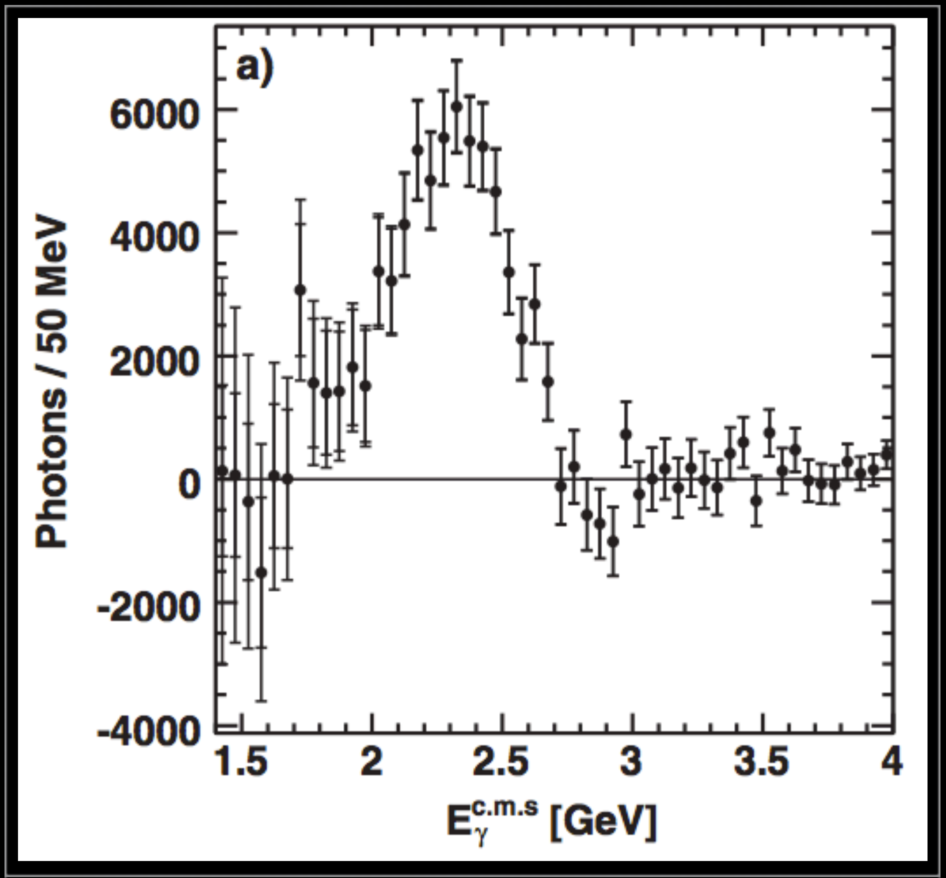
Introduction



- Total decay rate and CP Asymmetry
  - prove for the New Physics e.g. charged Higgs, SUSY
- Differential decay rate
  - photon as a messenger of the dynamics of the b-quark properties

Analysis Methods

- Fully Inclusive
  - measure the isolated photon only, small systematic bias
  - large statistics but large continuum background
  - smeared E_γ by B-boost
  - lepton tag
    - useful for continuum suppression and flavor tagging
- Hadronic Tag
  - fully reconstruct a hadronic B decay, measure the photon in the rest
  - continuum background is suppressed but very low efficiency
- Sum of Exclusive
  - fully reconstruct as many modes as possible
  - clearly measured E_γ and high efficiency
  - systematic bias due to missing modes

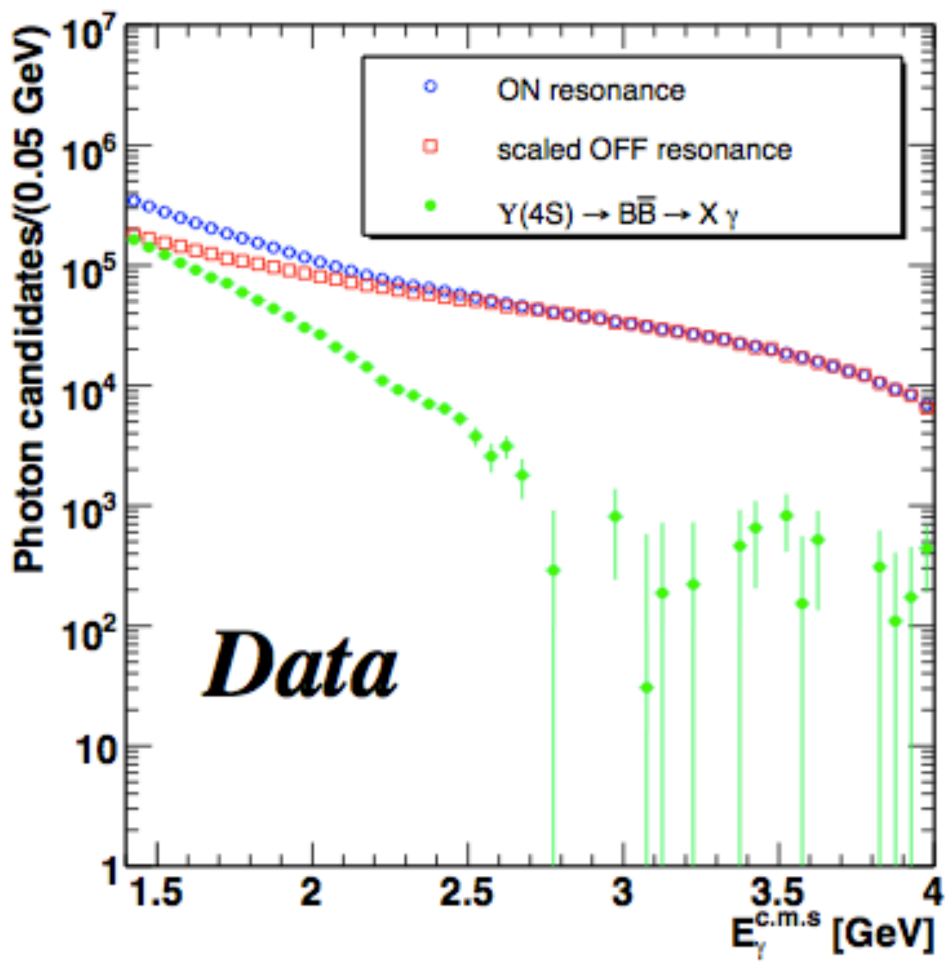


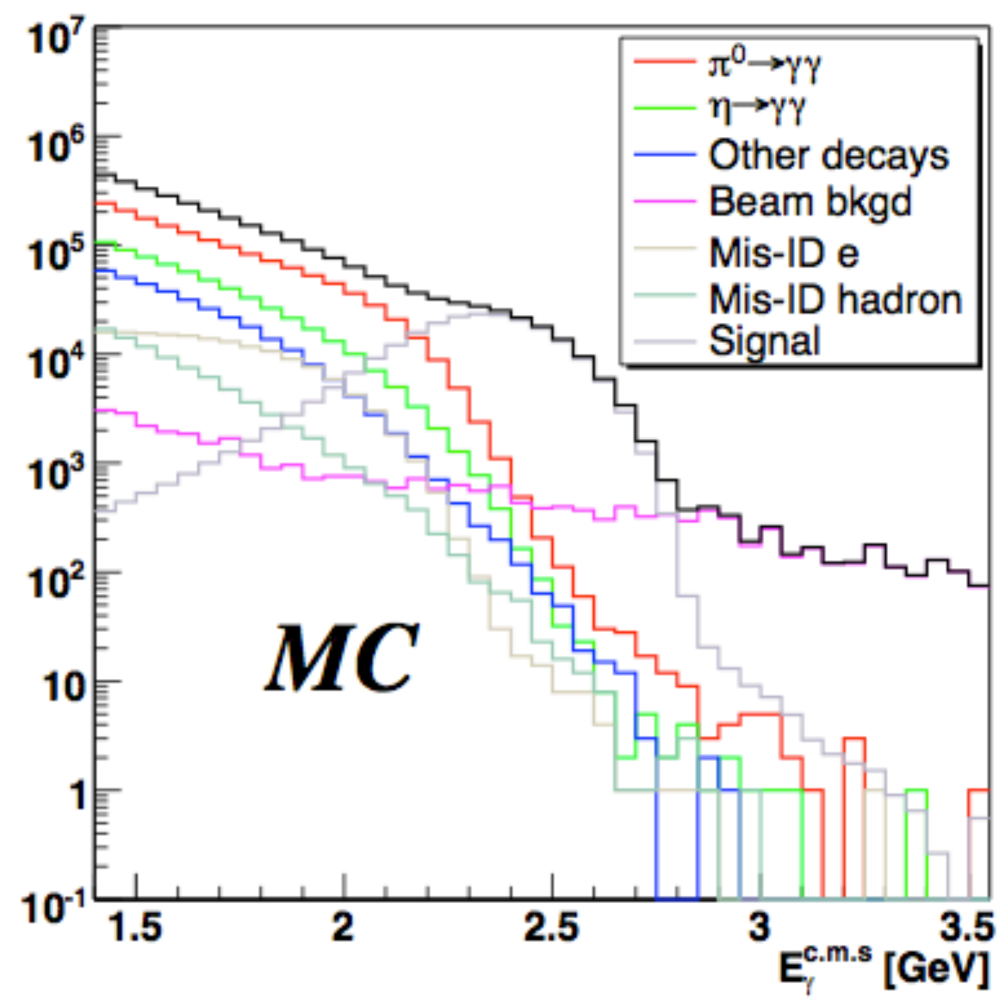
Fully Inclusive & Lepton Tag

World best measurement at Belle
PRL 103, 241801 (2009)

Fully Inclusive & Lepton tag

- Study with two method; fully inclusive & lepton tag.
- Find isolated photon in the EM calorimeter.
- High energy photon with $E_{c.m.s}$>1.4 GeV.
- Veto γ from π^0, η and Bhabha and suppress continuum with event topology
- Estimate continuum using OFF resonance data
- Estimate B decays using corrected MC sample; $B \to X(\pi^0/\eta)$



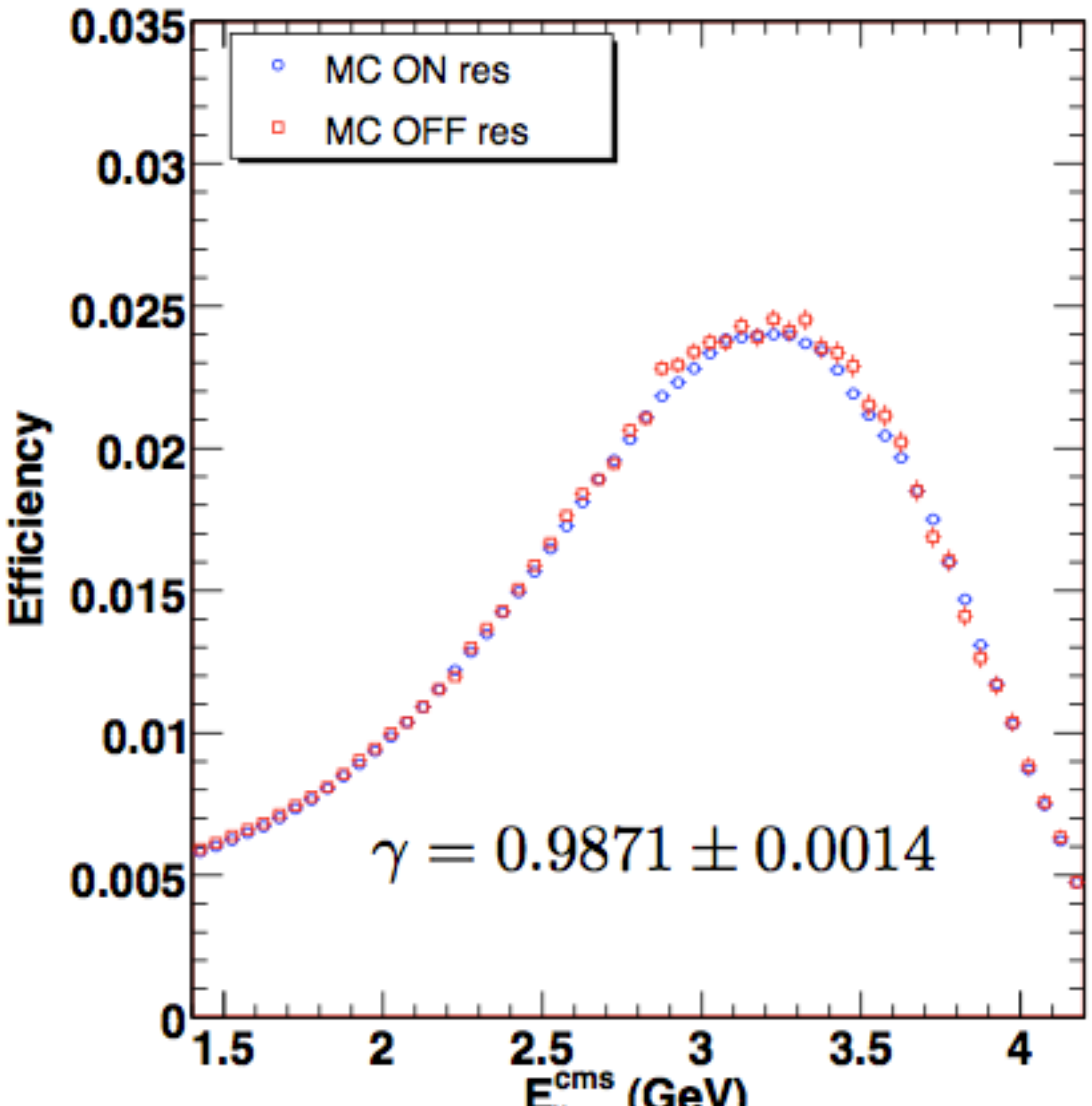


Continuum Subtraction

Continuum subtraction is performed considering difference

- b/w ON and OFF resonance for luminosity (α),
- efficiency of hadronic event (β) and of signal event (γ),
- photon multiplicity (F_N),
- photon mean energy (F_E).

$$N^{B\bar{B}}(E_\gamma^{\mathrm{c.m.s}}) = N^{\mathrm{ON}}(E_\gamma^{\mathrm{c.m.s.(ON)}}) - \alpha \cdot \beta \cdot \gamma \cdot F_N \cdot N^{\mathrm{OFF}}(F_E E_\gamma^{\mathrm{c.m.s.(OFF)}})$$



$$\alpha = \frac{\mathcal{L}_{\mathrm{ON}} dt}{\mathcal{L}_{\mathrm{OFF}} dt} \cdot \frac{s_{\mathrm{OFF}}}{s_{\mathrm{ON}}} = 8.7577(\pm 0.3\%)$$

$$\beta = \frac{\varepsilon^{\mathrm{ON}}_{\mathrm{Hadronic}}}{\varepsilon^{\mathrm{OFF}}_{\mathrm{Hadronic}}} = -0.9986 \pm 0.0001$$

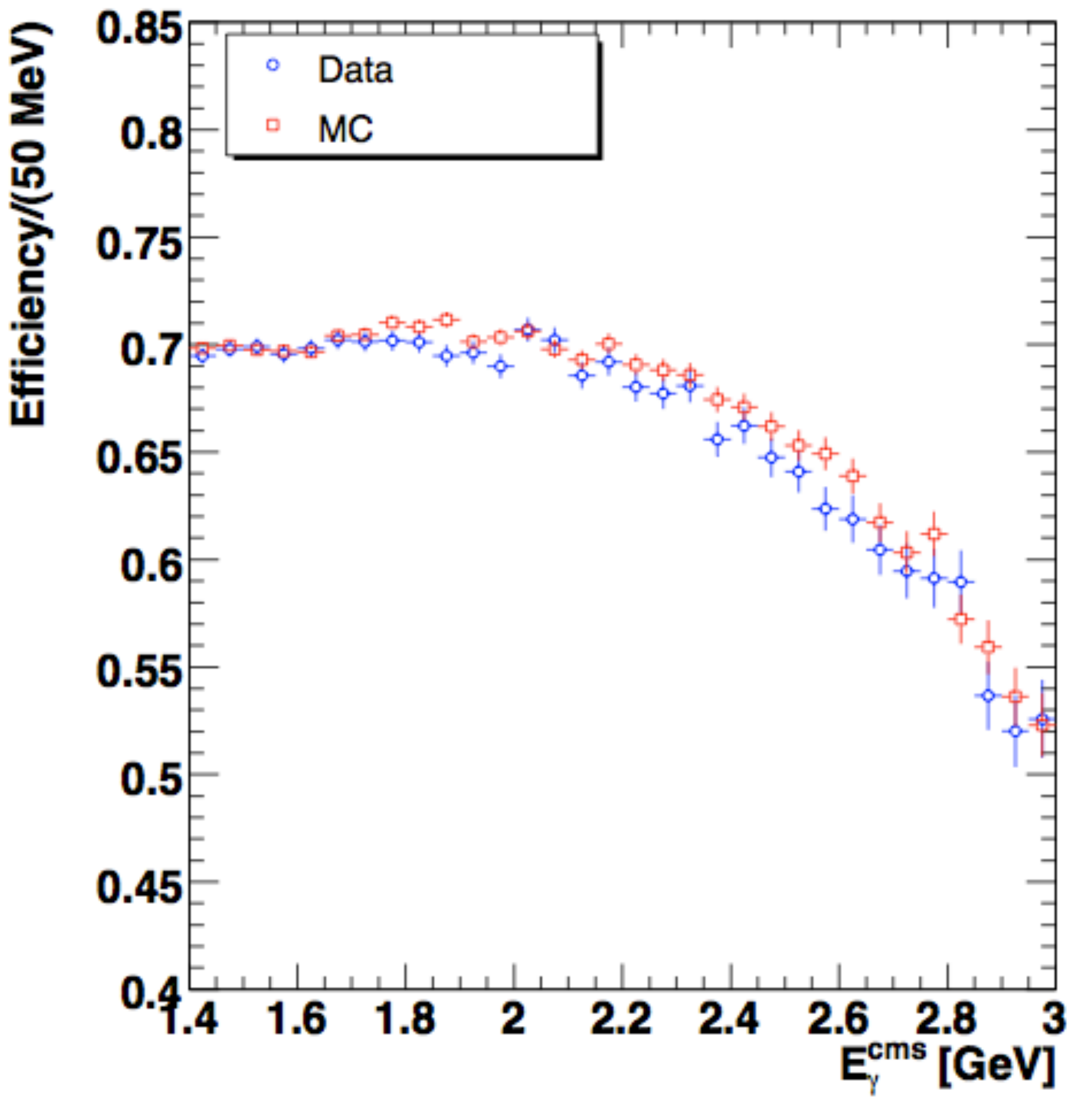
$$\gamma = \frac{\varepsilon^{\mathrm{ON}}_{B\to X_s\gamma}}{\varepsilon^{\mathrm{OFF}}_{B\to X_s\gamma}}$$

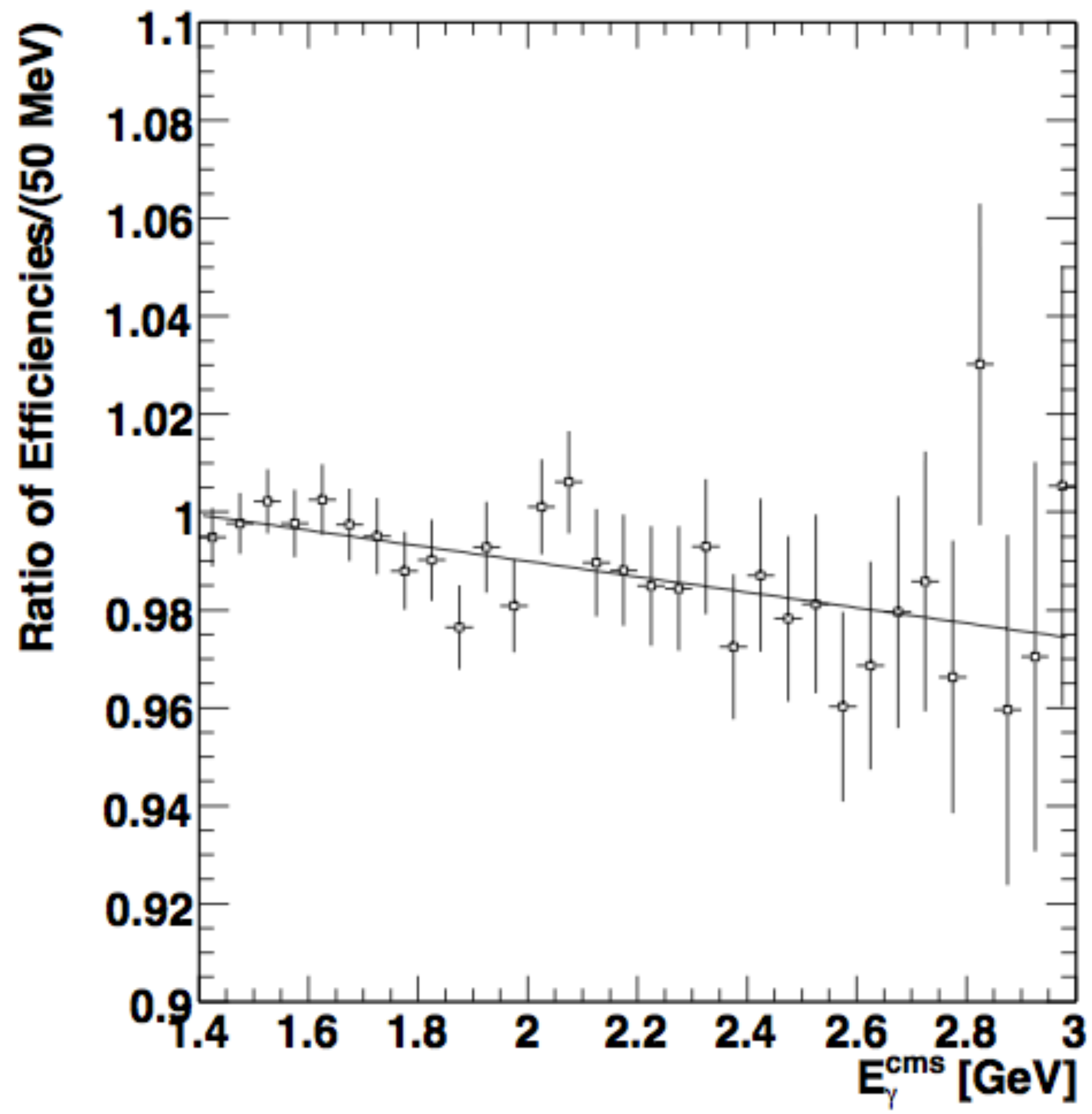
F_N = 1.0009
(difference in photon multiplicity)

F_E = 1.0036
(difference in photon mean energy)

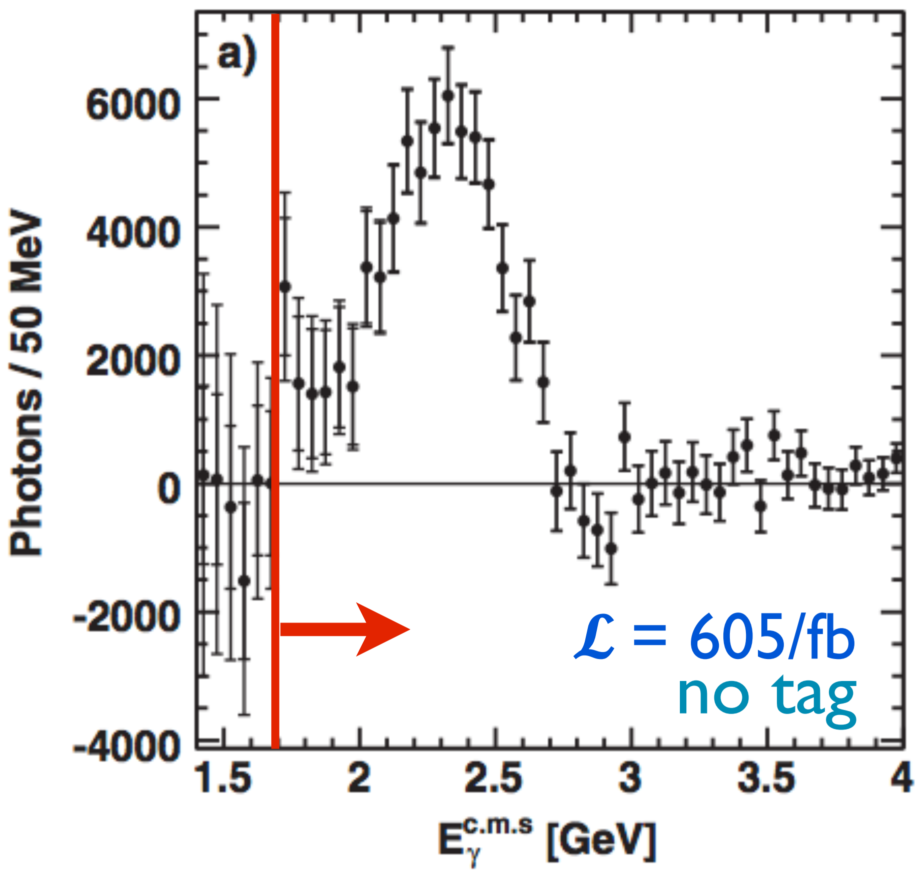
Efficiency Corrections

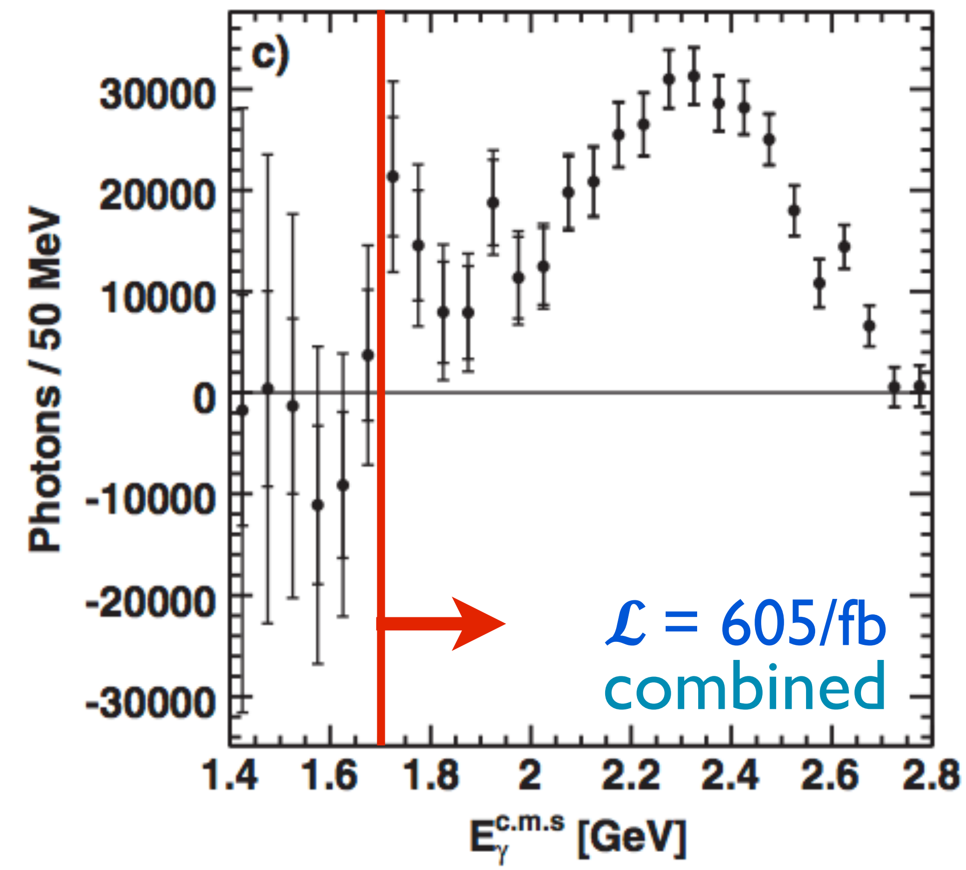
- Selection efficiency in MC and data from the control sample
  - e.g. π^0 veto efficiency in a sample of partially reconstructed $D^* \to D \to K\pi\pi^0, \pi^0 \to \gamma\gamma$



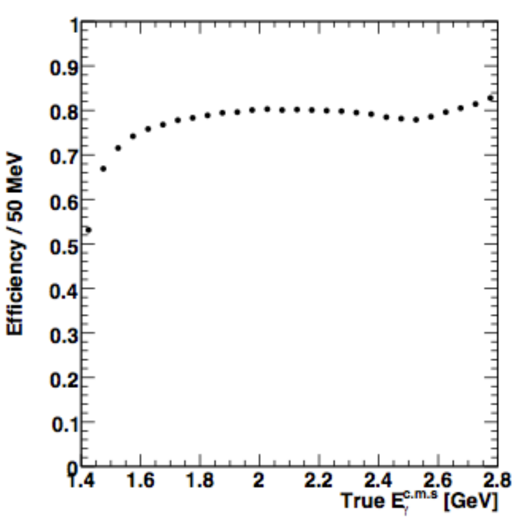


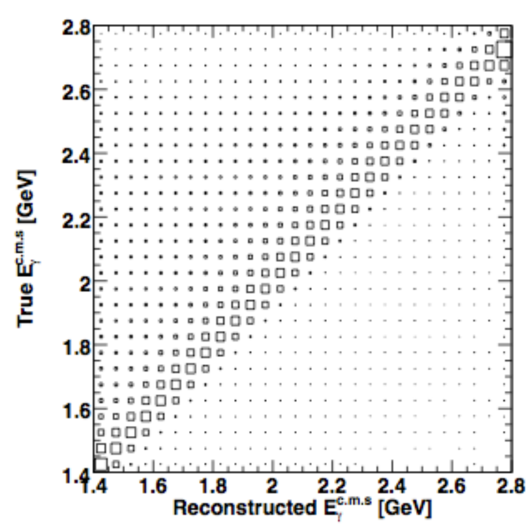
Extracted Photon Energy Spectrum

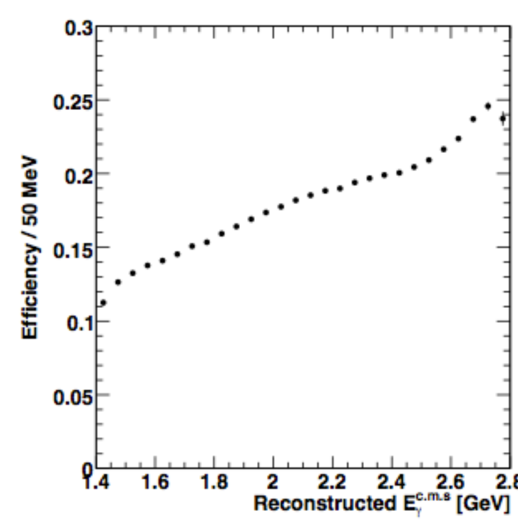




- Corrected raw photon energy spectrum







Combine no-tag & lepton-tag

Selection Efficiency

$$R(E_\gamma^{\rm meas}) = \frac{N_{\rm rec.}}{\varepsilon_{\rm sel.}}$$

Unfolding Procedure

$$M(E_\gamma^{\rm true}) = A^{-1} R(E_\gamma^{\rm meas})$$

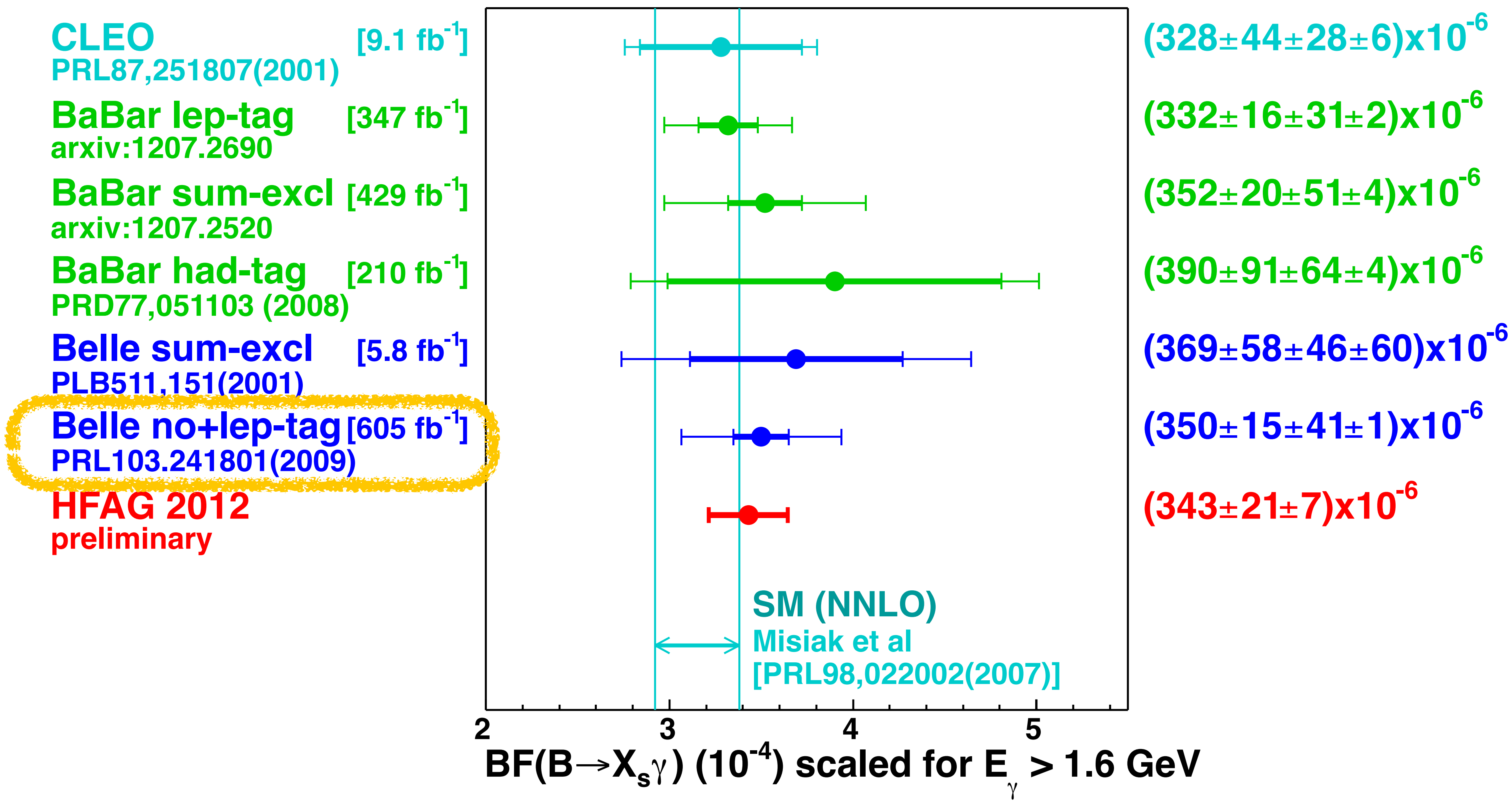
Detection Efficiency

$$T(E_\gamma^{\rm true}) = \frac{M_{\rm unfolded}}{\varepsilon_{\rm det.}}$$

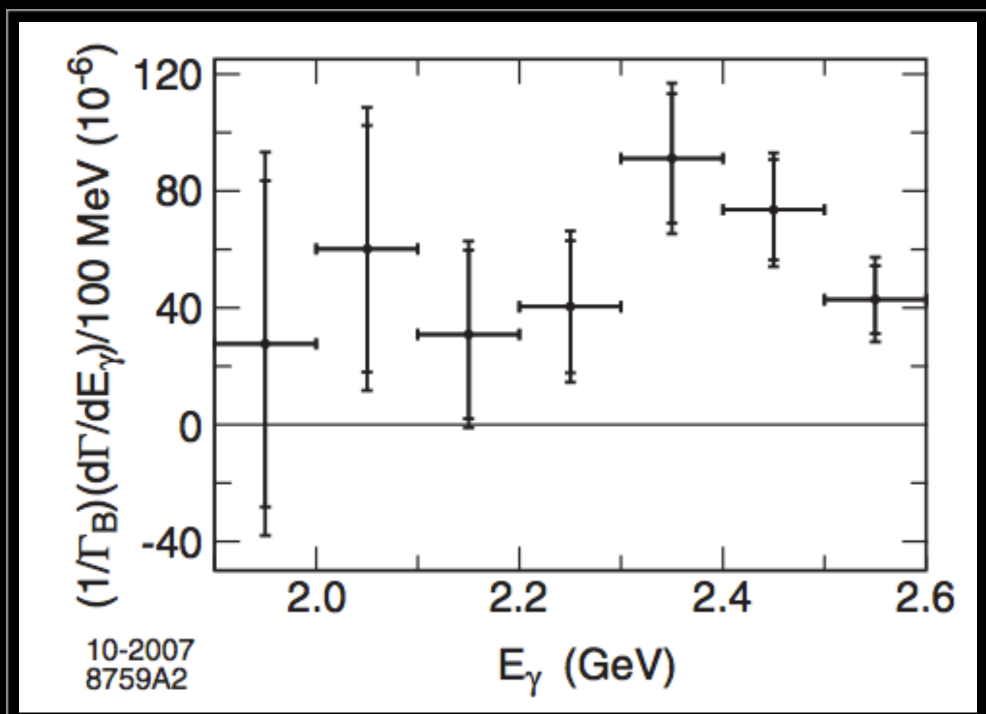
Branching Fraction (Exp.)

Belle no-tag + lepton-tag for Eγ>1.7 GeV

$\mathcal{B}(B\to X_s\gamma) = (345 \pm 15 \pm 40) \times 10^{-6}$



If we use Eγ>1.8 GeV result, Belle's no-tag + lepton-tag result becomes $(347 \pm 13 \pm 26 \pm 2) \times 10^{-6}$



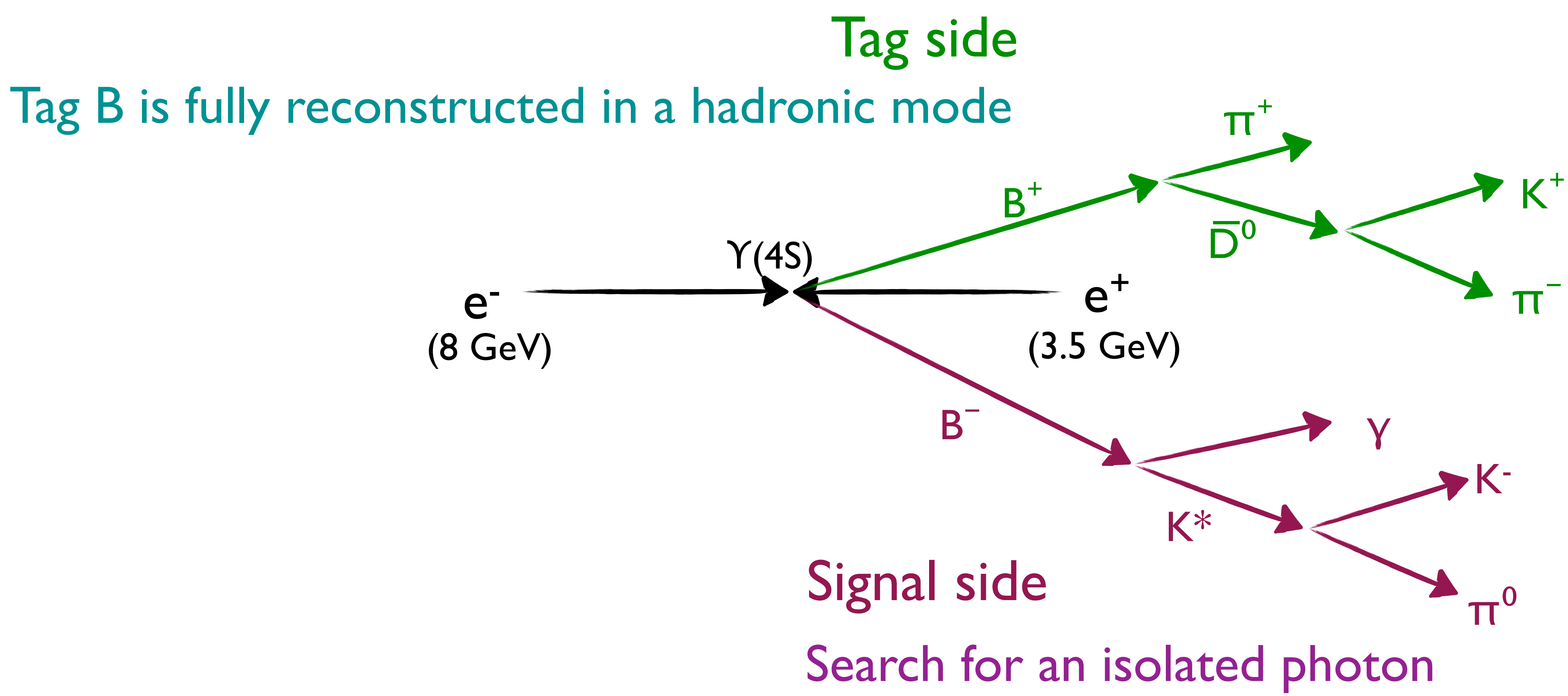
Hadronic Tag

Comparison with BaBar

PRD 77, 051103(R) (2008)

no Belle result so far

Hadronic Tag Method

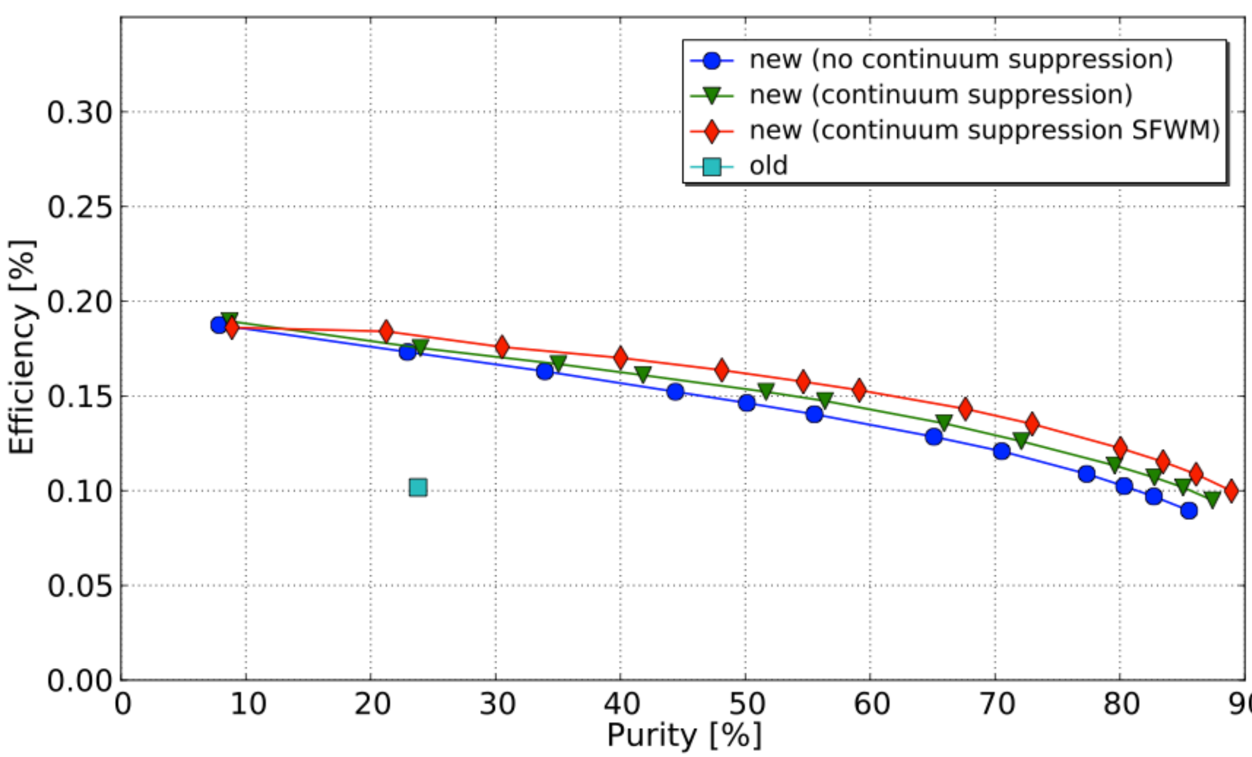


- Advantage
  - small continuum background extracted from fit
  - information of B flavor, charge and momentum → enables to study asymmetries
- Disadvantage
  - low efficiency of fully reconstructed B (tag efficiency ~ 0.45%)

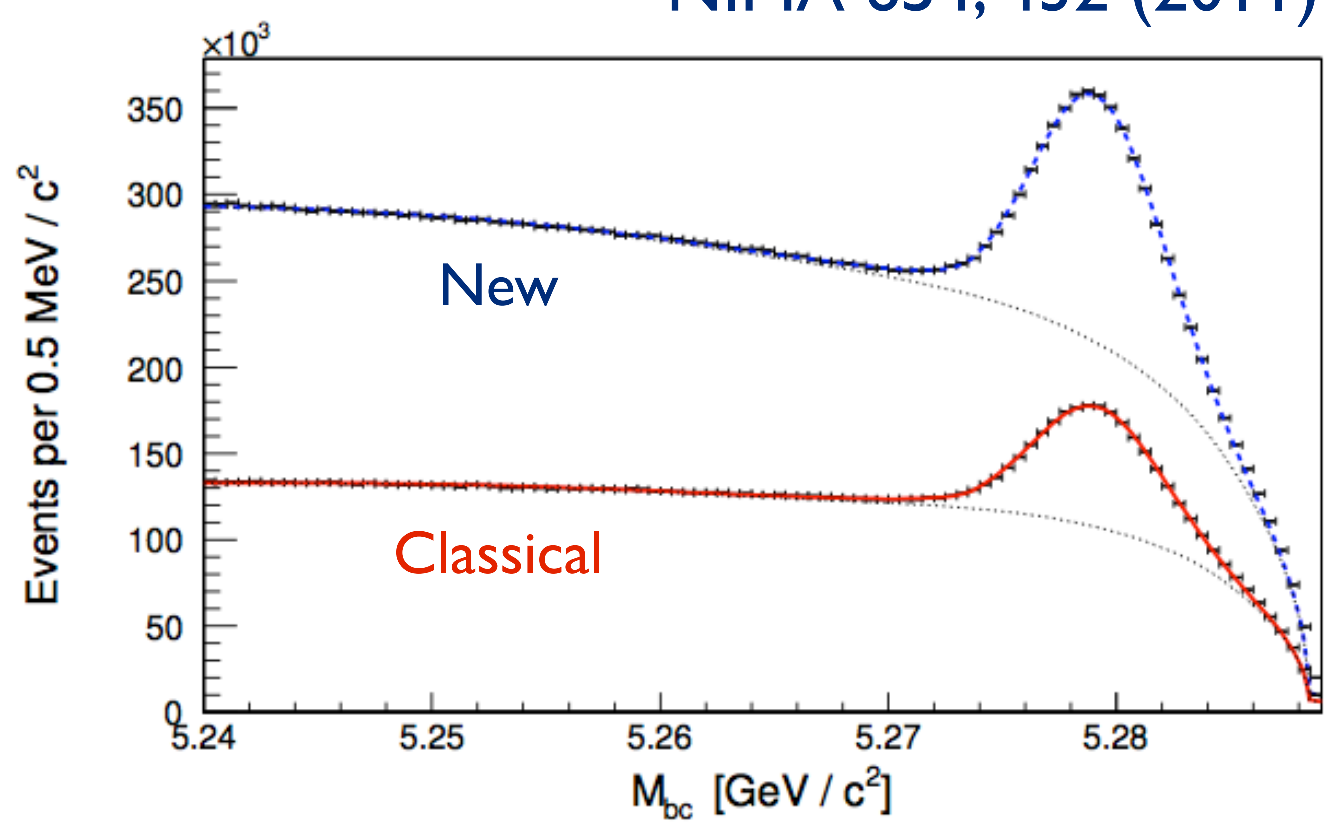
Improved Hadronic Tag at Belle

- More decay modes.
- Event selection by NeuroBayes neural net program.
- Efficiency and purity can be adjusted by NeuroBayes output.
- Easy to include the continuum suppression in the candidate selection process.
- Already used in new Belle $B \to \tau\nu$ and other studies.

NIMA 654, 432 (2011)



Efficiency and purity are decided based on the NeuroBayes output cut



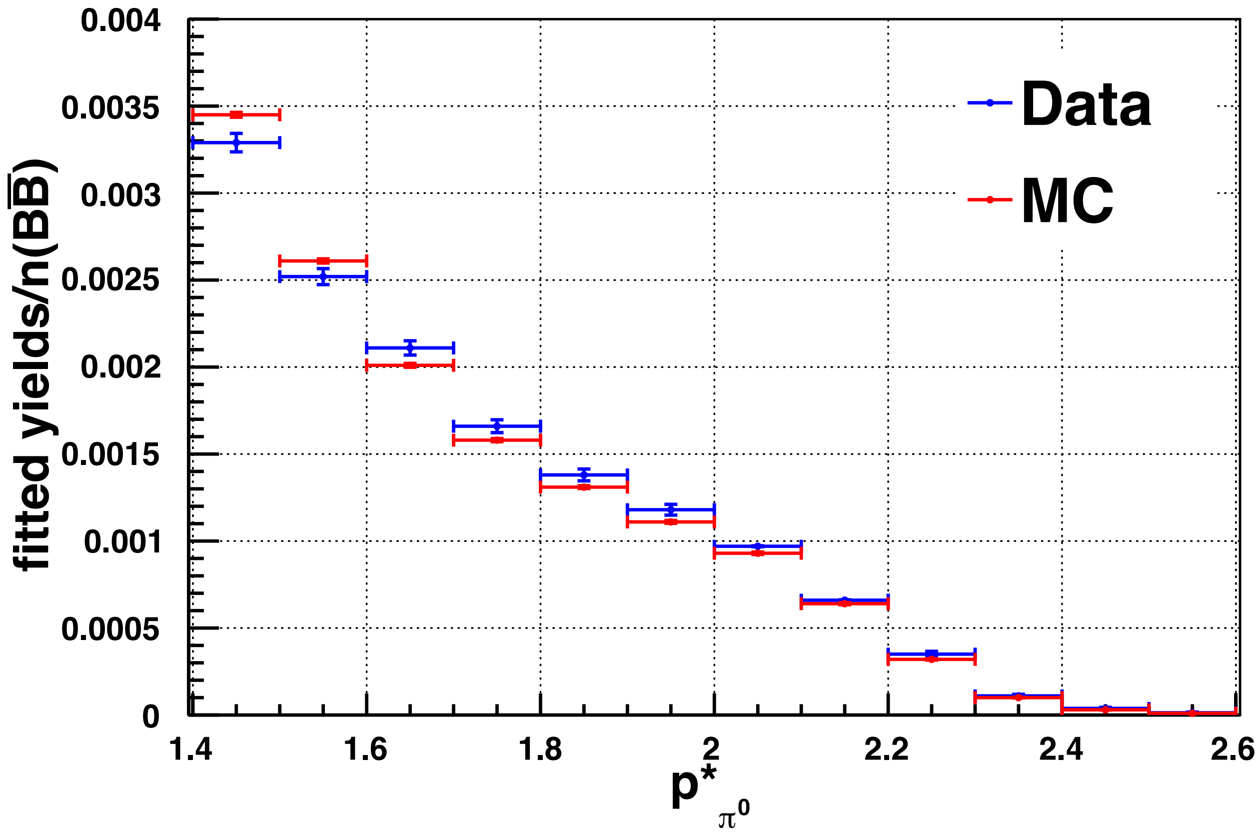
Improved efficiency by a factor of ~2 at the same purity level

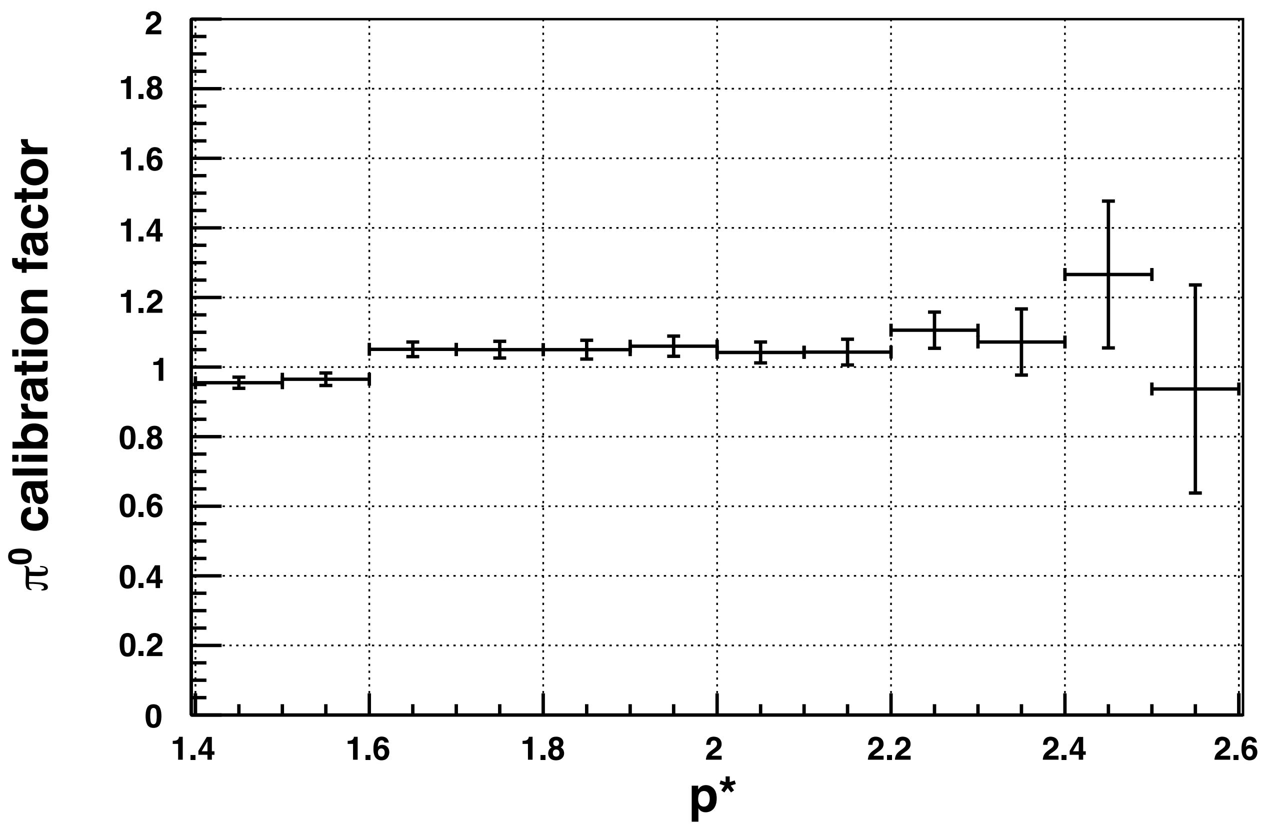
Analysis Strategy

- Hadronic tag with $|\Delta E|<0.06$ GeV and good tag quality
- Select good photon (optimized for E_γ in 1.8-2.0 GeV)
  - $1.4<E_\gamma<2.6$ GeV, π^0/η veto, off-timing QED background veto and E9/E25
- Background calibration for subtraction
  - π^0/η : MC/data difference is measured as a function of $p^*_{(\pi^0/\eta)}$
  - others : examine the contribution in MC
- Raw signal yield by M_{bc} fit
- Unfold the spectrum
- Measure the differential branching fraction

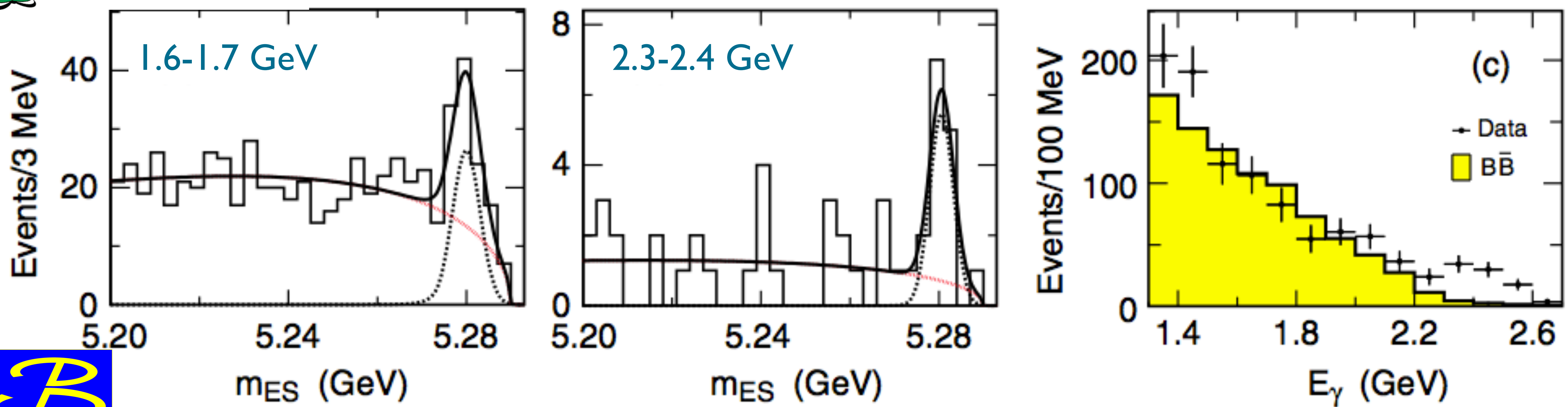
π^0 Calibration

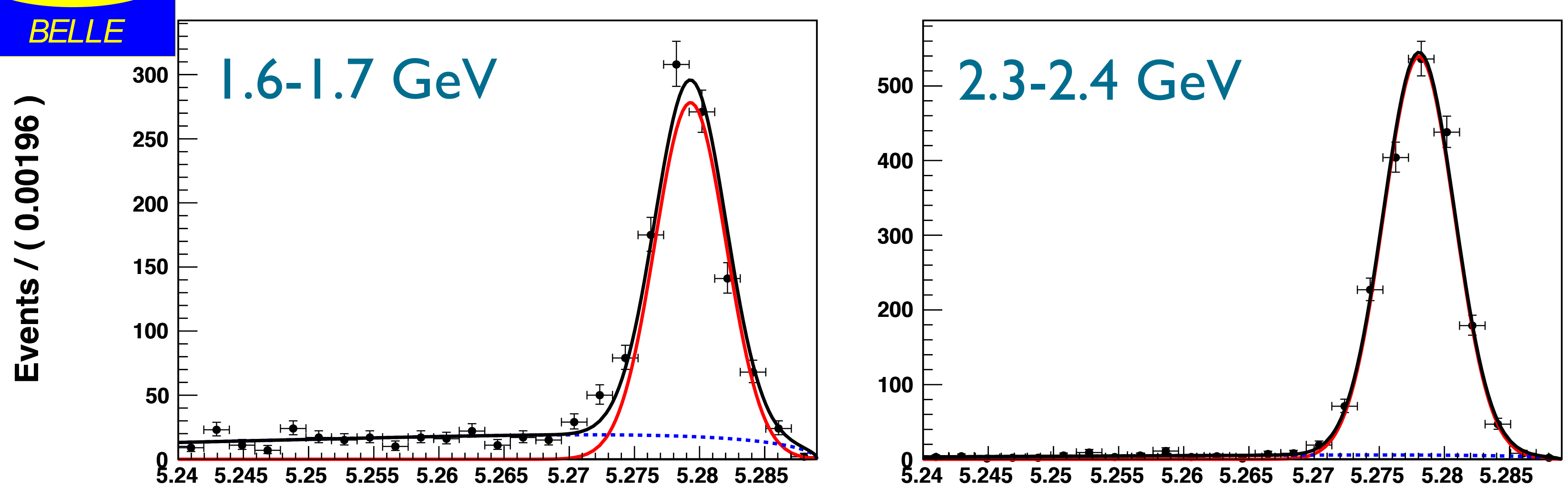
- Comparison of normalized yields in MC and data with $B \to X\pi^0$
- Estimate B decays using calibrated MC sample;

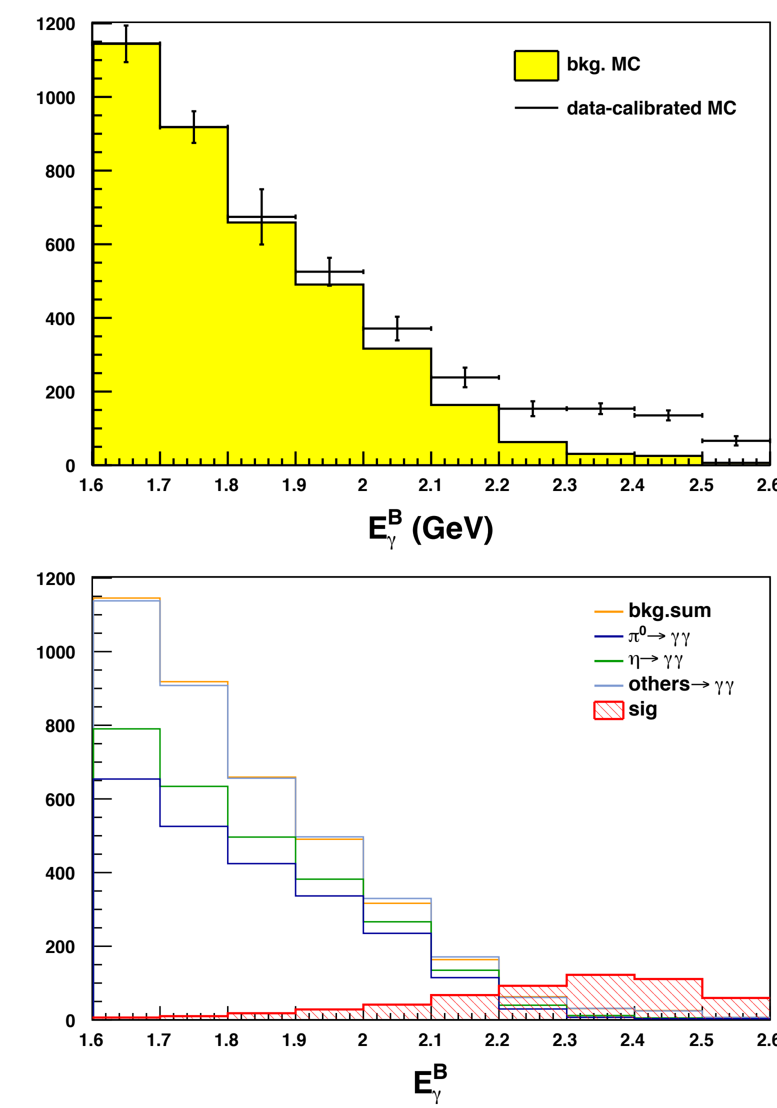




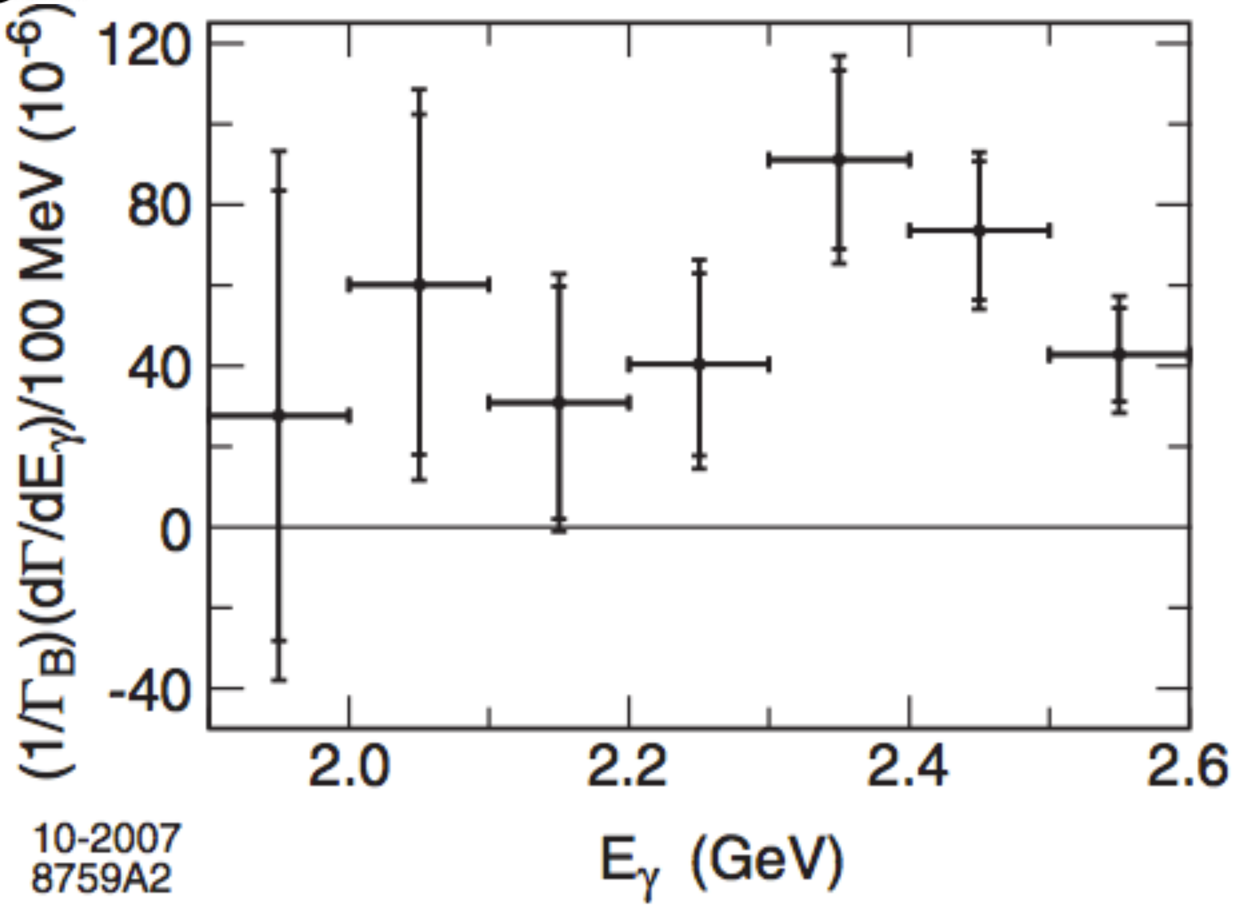
Data-calibrated MC





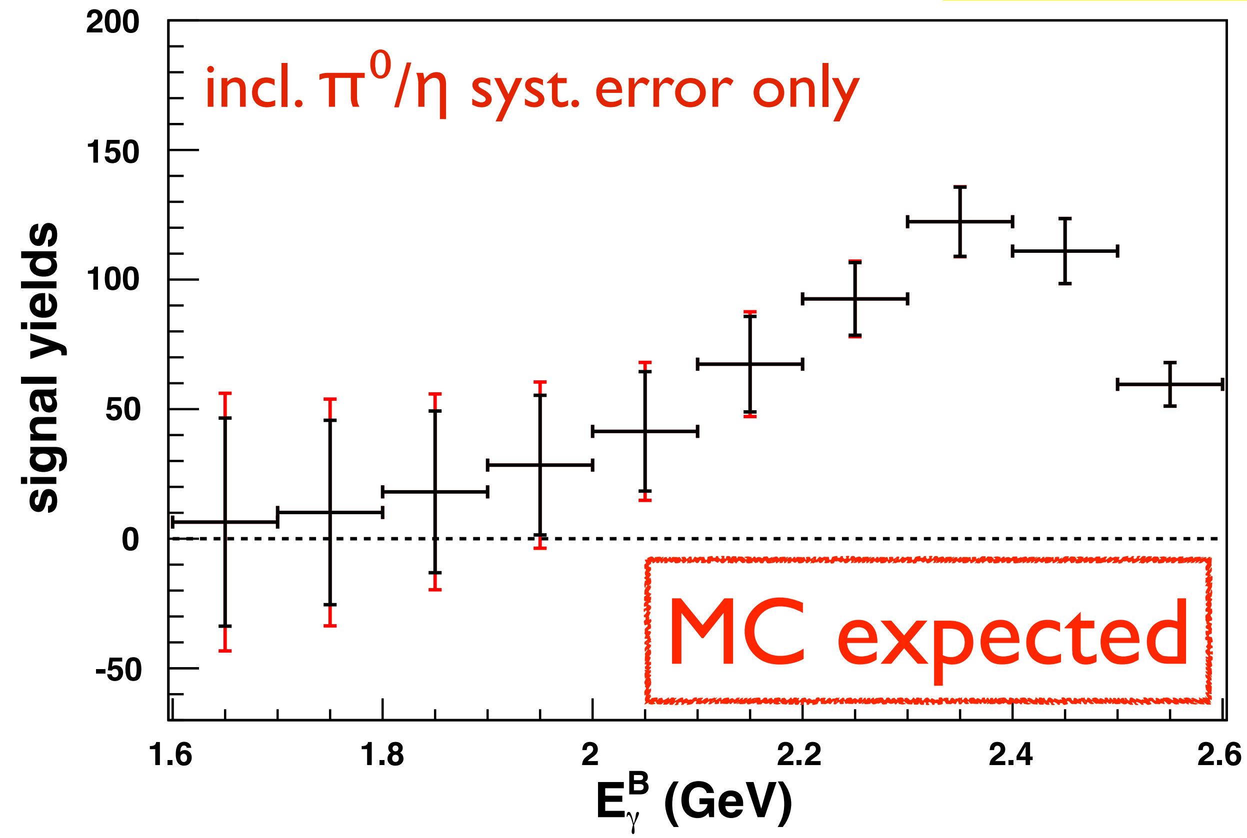


Photon Energy Spectrum



$\mathcal{L}$ = 210/fb

$\mathcal{B}(B \to X_s\gamma, E_\gamma > 1.9$ GeV$)$
$= (3.66 \pm 0.85 \pm 0.60) \times 10^{-4}$



$\mathcal{L}$ = 710/fb

Improved result is expected with new hadronic tag algorithm on full Belle data set.

At Belle II, hadronic tag is a promising method, since it will be still statistics dominated.

Summary

- $b \to s\gamma$ study
  - interesting topic at B factory; beyond Standard Model
  - world best measurement at Belle
  - prospect for the hadronic tag analysis

- Expectation
  - better results with improved analysis tools and increased data sample soon
  - more precise measurement at Belle II