$B \to X_s \gamma$ study
with hadronic tagging method in *Belle* collaboration

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INTRODUCTION

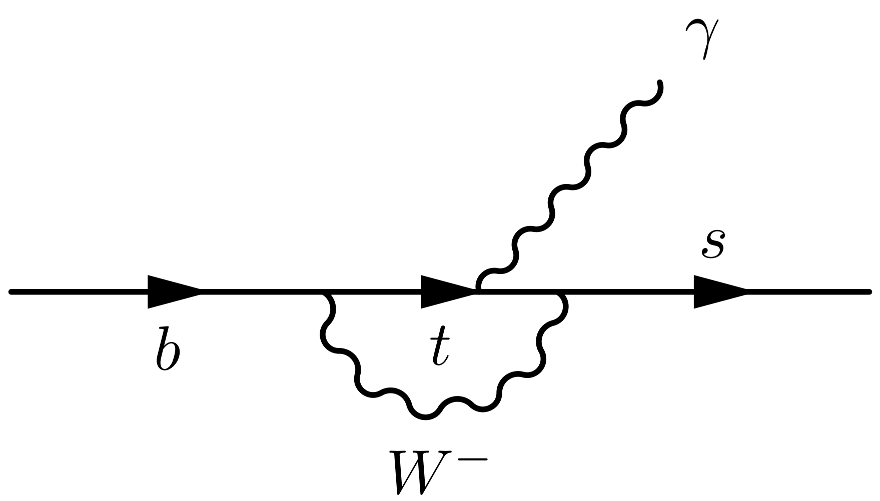


Figure 1: FCNC process of $b \to s\gamma$ decay

As for the tree level decay of b→s**γ** is forbidden in the Standard Model, the decay takes place at least at the loop level with FCNC as a leading order penguin diagram as Figure 1.

(The virtual W might be replaced by $H^{\pm}$ or non-SM particles, which leads to enhanced or suppressed branching fraction.)

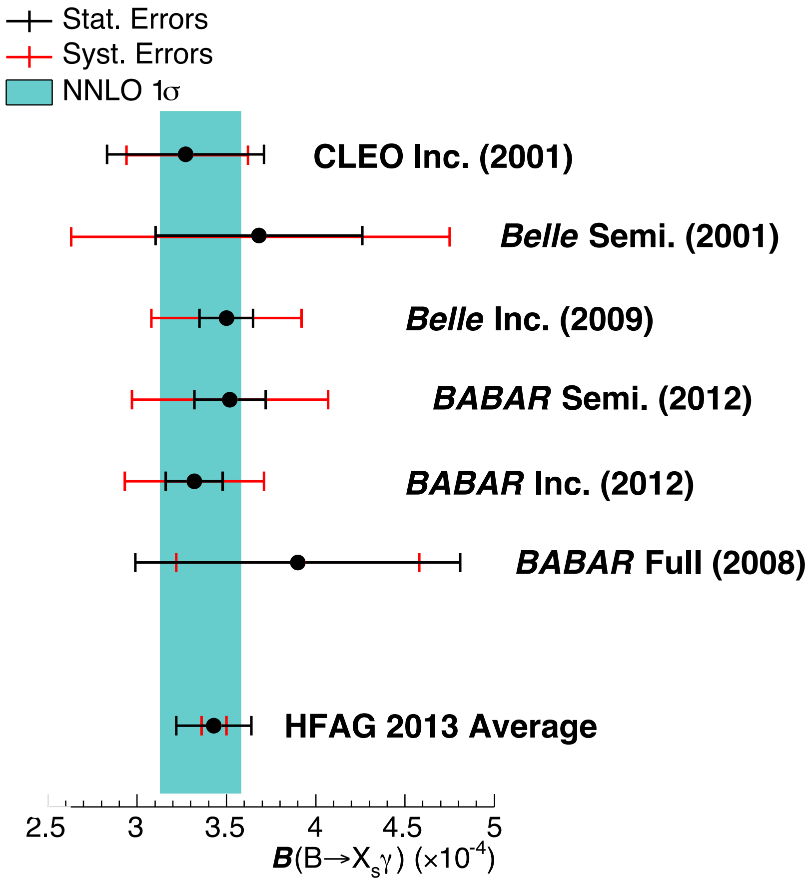
The most recent NNLO result

$$\mathcal{B}(B \to X_s\gamma)_{NNLO} = (3.36 \pm 0.23) \times 10^{-4}$$

The most recent HFAG average

$$\mathcal{B}(B \to X_s\gamma)_{\rm HFAG} = (3.43 \pm 0.21 \pm 0.07) \times 10^{-4}$$

The current experimental average agrees well on the recent NNLO result with ~0.3σ deviation.



INTRODUCTION

Through this analysis, we will be able to obtain ..

B.F, the CP asymmetry, A_{CP} and the **isospin asymmetry** Δ_{0-} of $b \to s\gamma$.

Current PDG

$$A_{CP} = -0.008 \pm 0.029$$

$$\Delta_{0-}(B(B \to X_s\gamma)) = -0.01 \pm 0.06$$

Especially, provided the info. of the charge of B-meson by *the hadronic tagging method*, we can ***directly*** obtain the isospin asymmetry.

EKP fullrecon module fully reconstructs one of B-mesons (B_{tag}) in an event via hadronic decay channels (e.g. $B \to D\pi$) providing the info. on ***p***, ***E***, ***q***, etc. from which we can derive the info. of the other B meson (B_{sig}) directly. (The crucial concept of the hadronic tagging method !)

QUALITY CONTROL VARIABLES

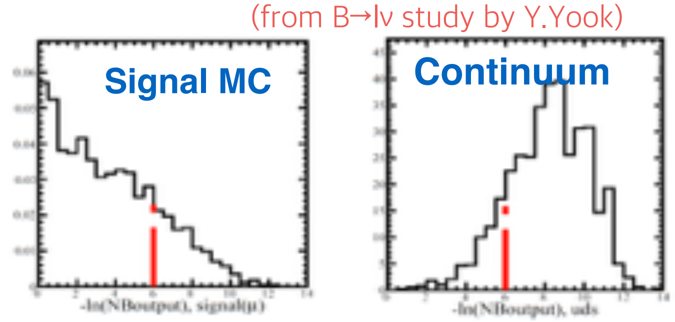
$$M_{bc} = \sqrt{((E_{CM}/2)^2 - |p_{tag}|^2}$$

$$\Delta E = E_{B_{tag}} - E_{CM}/2$$

E_{CM} : (2 x Beam energy) in CM frame
p_{tag} : The momentum of B_{tag} in CM frame
E_{Btag} : The energy of B_{tag} in CM frame

NB_{out} : Neuro-bayse Output

(from B→lν study by Y.Yook)



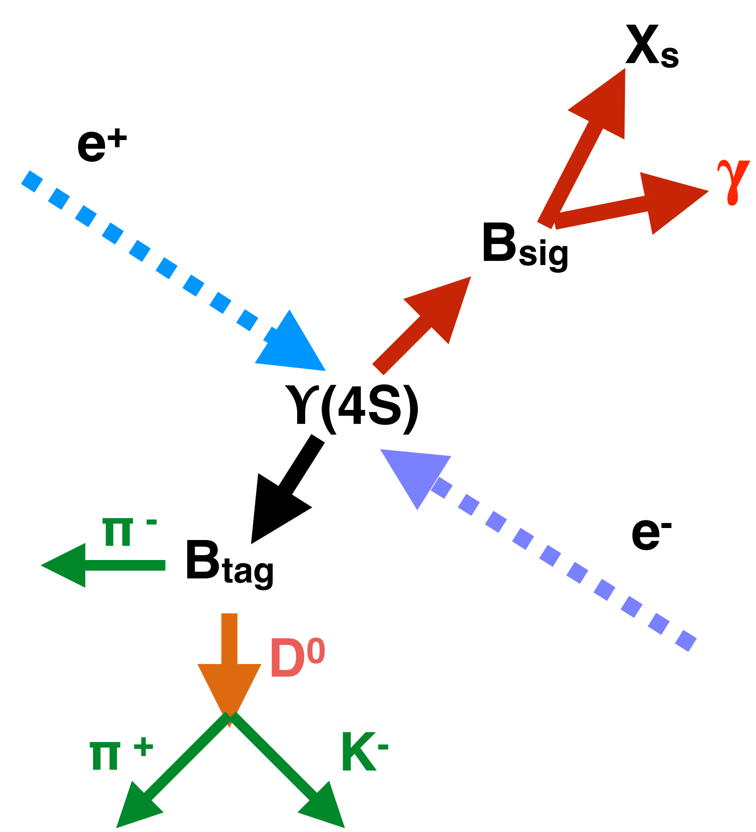


Figure 3. A schematic view of the hadronic tagging method via *B→Dπ channel*

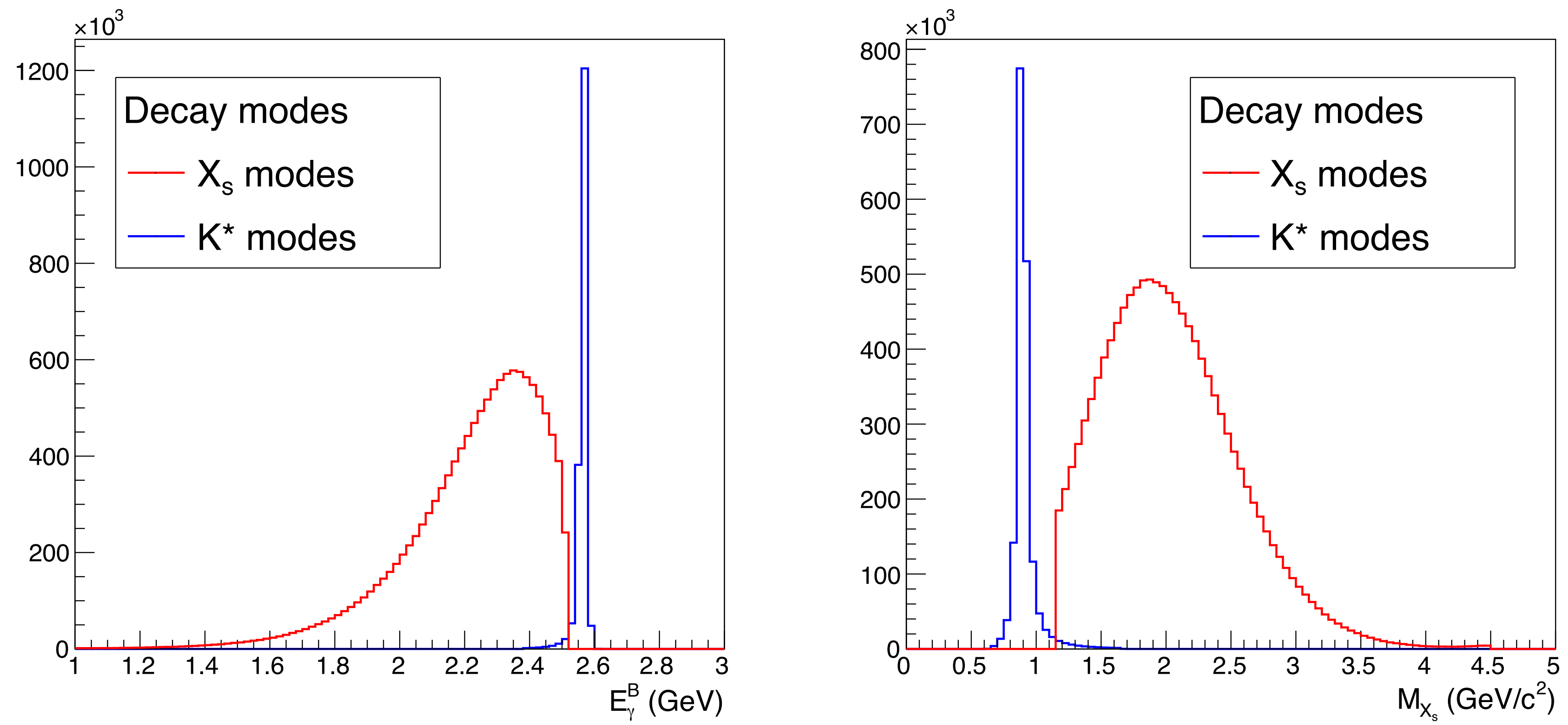
Introduction

Signal MC

Kagan-Neubert model shaped with heavy quark parameters employed for signal modeling.

Current HFAG global fit for the heavy quark parameters

$$m_b = 4.574 \pm 0.032\ \text{GeV}, \qquad \mu_\pi^2 = 0.459 \pm 0.037\ \text{GeV}^2$$



*B→K*γ* channels are separately generated for more realistic modeling.

Events as ~25 times as many $N_{expected}$ in Data was generated

Selection Criteria

EKP fullrecon

Best B_{tag} Selection

(For the B_{tag} with the highest o_{tag})

$$o_{tag} > 0.1$$

$$5.24 < M_{bc}^{tag} < 5.29\text{GeV}$$

$$|\Delta E| < 0.06\text{GeV}$$

Contiuum Suppression

NeuroBayes
with event shape variables

Signal Candidate Selection

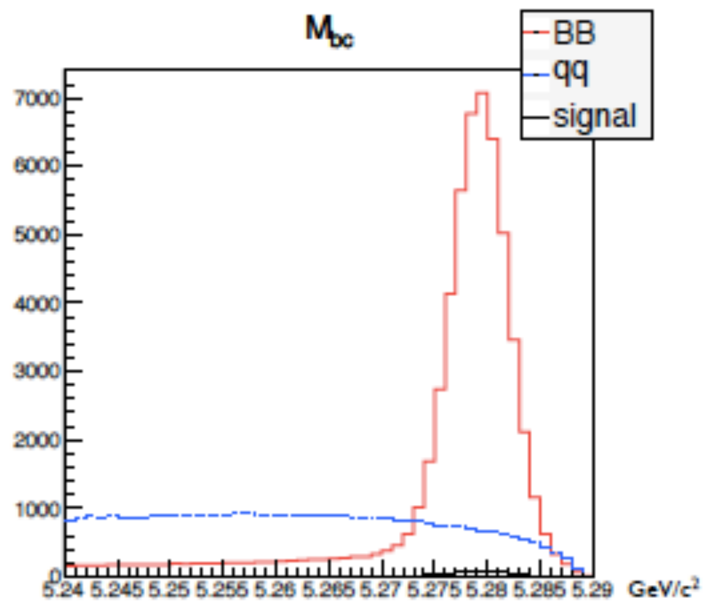
Most energetic (in B rest frame) gamma
among sig-side gammas.

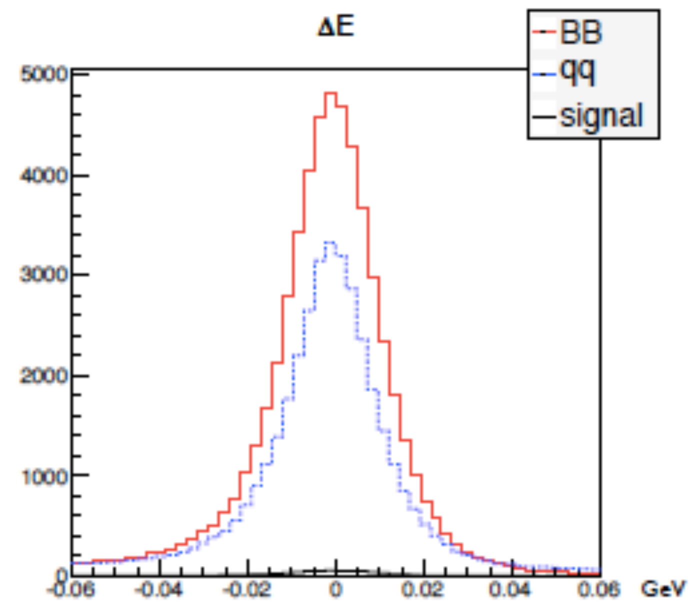
$$E^{B}_{\text{candi.}\gamma} > 1.3\text{GeV}$$

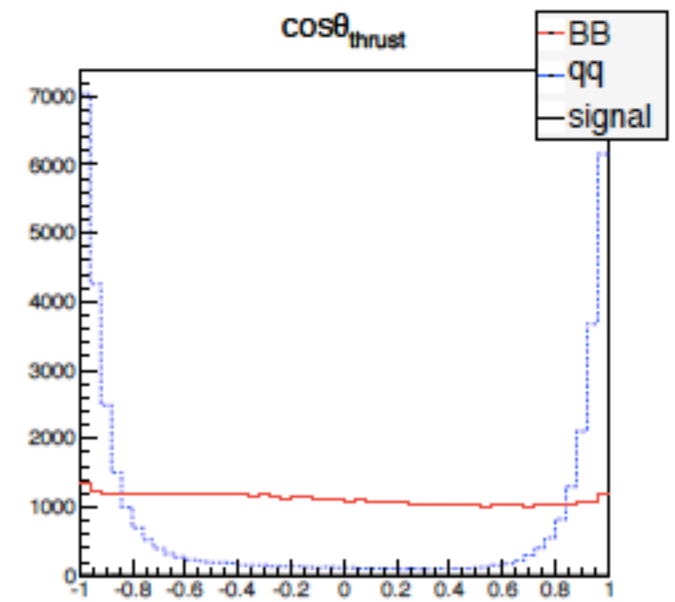
Signal Isolations

1. TDC off-timing veto
   - to suppress beam backgrounds
2. π^0 & η veto
   - based on P. Koppenburg's study
3. E9/E25 (photon purity)
4. electron radiation veto
   - Reject photons too close to electron track

Best B Selection







	Simulated	After fullrecon & pre-selection	Efficiency
Signal	1.45E+07	2.11E+04	0.15%
Generic	3.86E+09	1.21E+07	0.31%
Continuum	1.16E+10	5.32E+06	0.05%

Table. The number of event before/after the fullrecon & pre-selection of sig/Generic/Continuum.

All MC available in KEKCC are employed

< Multipliers to corresponding # of events in DATA>

10x generic $B\bar{B}$

6x continuum

50x Rare B decay set

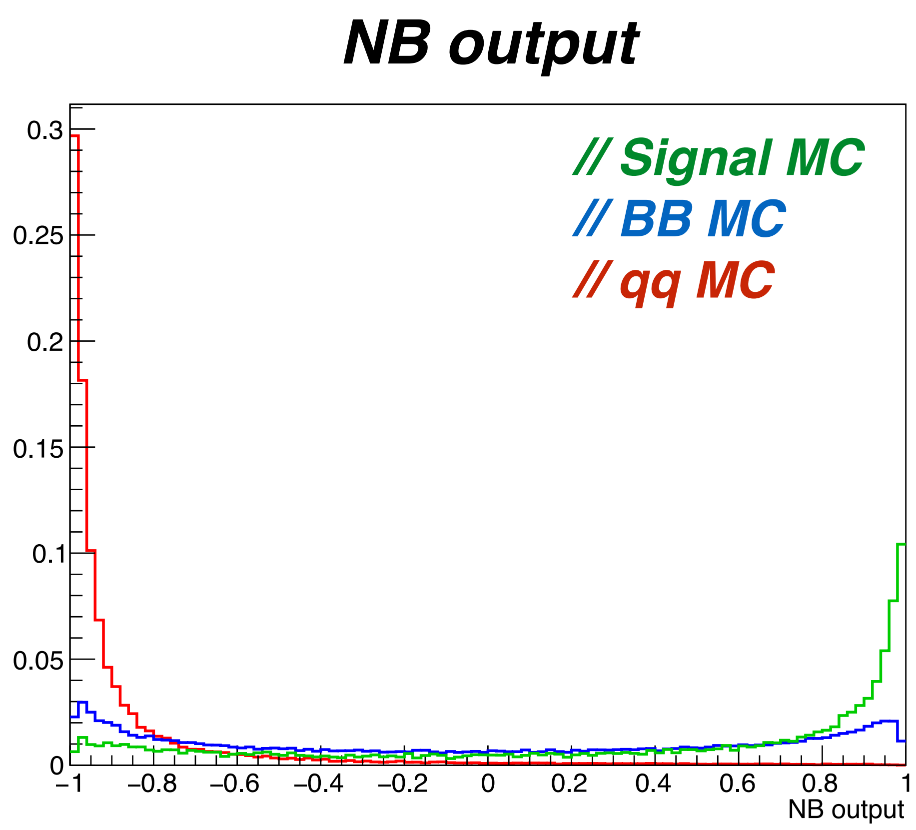
20x Ulnu decay set

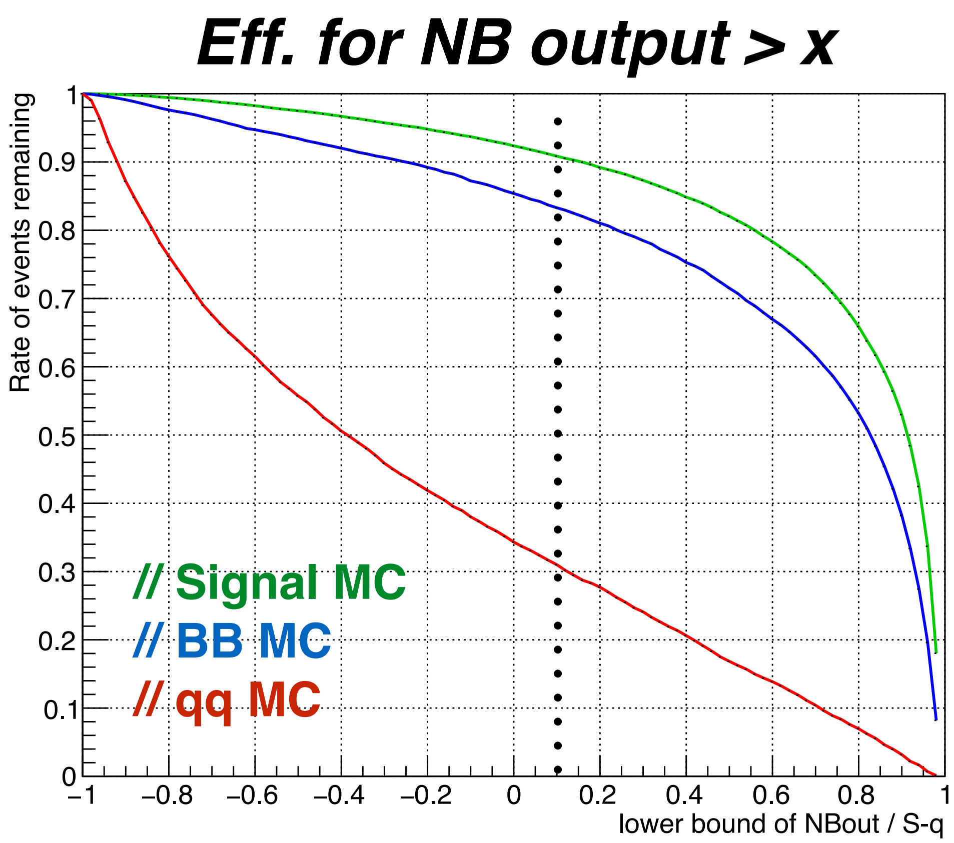
Continuum Suppression using NeuroBayes

- Test Input Variables - Event Shape Variables

O_{tag}, $|\cos\theta_{thrust}|$, Missing M^2, E_T, Super-Fox-Wolfram moments, Sphericity, Aplanarity, and $\cos\theta_B$

- NB output distributions & performance





For signal $E_\gamma > 1.9$ Region

$SqNB_{out} > 0.1$ is required

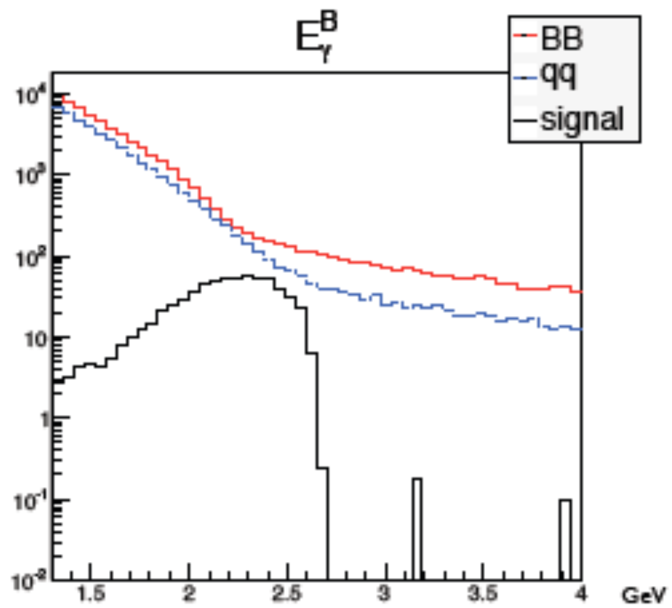
90% of signal events are reserved while rejecting 70% of the continuum events

Selection Criteria

Signal Candidate Selection

The most energetic (in B rest frame) photon among sig-side gammas.

$E_\gamma{}^{B}{}_{candi}$ > 1.3 GeV required



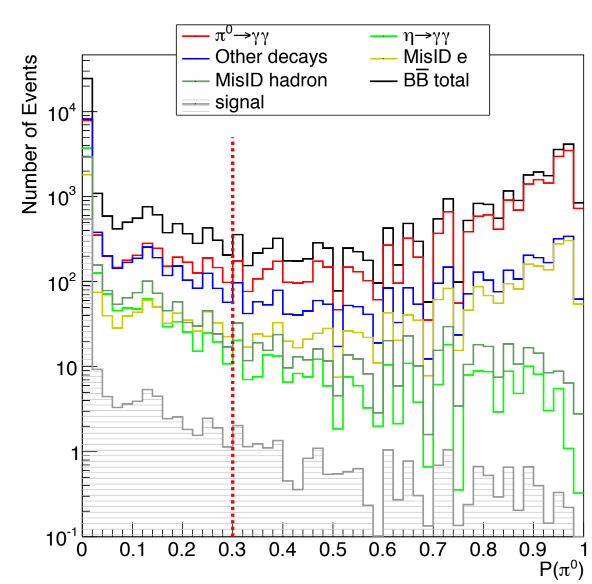
Signal Isolations

1. Beam background rejection

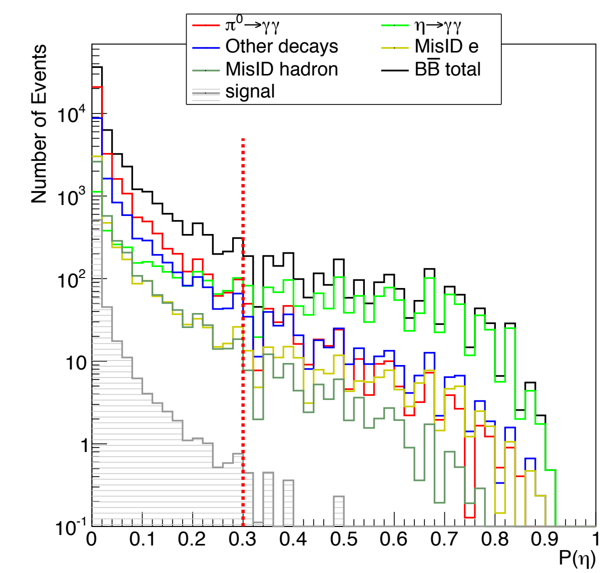
Using ECL trigger timing information

2. $\pi^0/\eta \rightarrow \gamma\gamma$ rejection

Using probability distribution obtained by control samples in the mass & photon energy

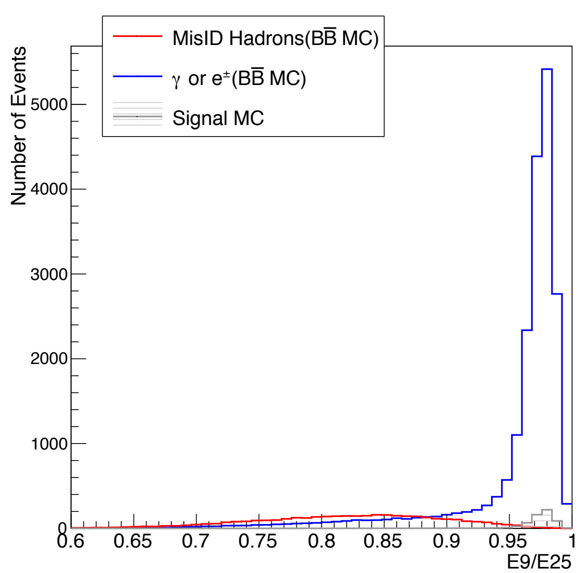


Red($\pi^0\rightarrow\gamma\gamma$) peak around 1



GR($\eta\rightarrow\gamma\gamma$) shows high prob.

3. E9/E25 > 0.95



E9 : E deposited in 3X3 ECL cluster
E25 : E deposited in 5X5 ECL cluster

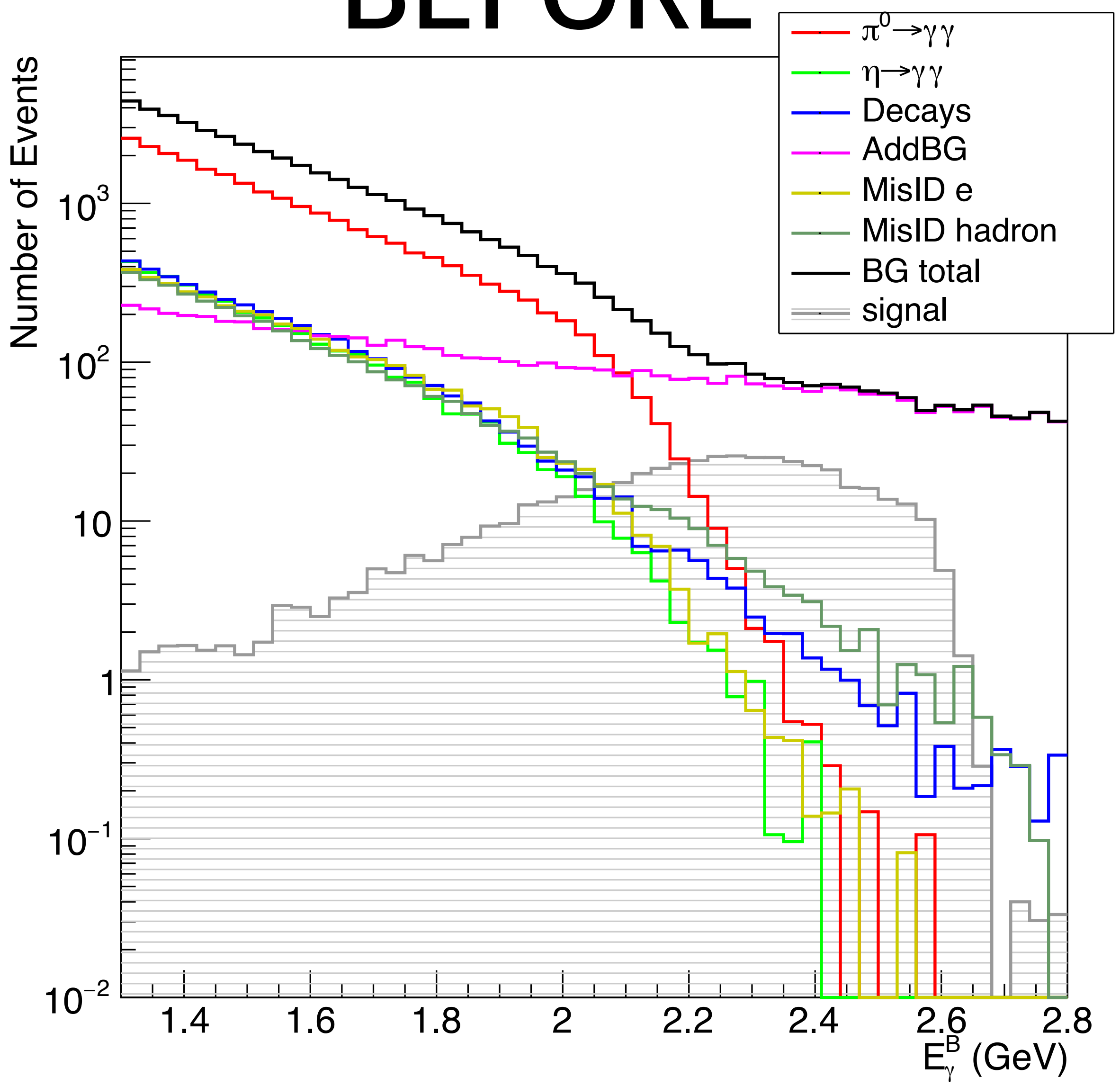
We can reject a lot of bkg mis-identified as photon, especially most of hadron showers

4. e radiation veto

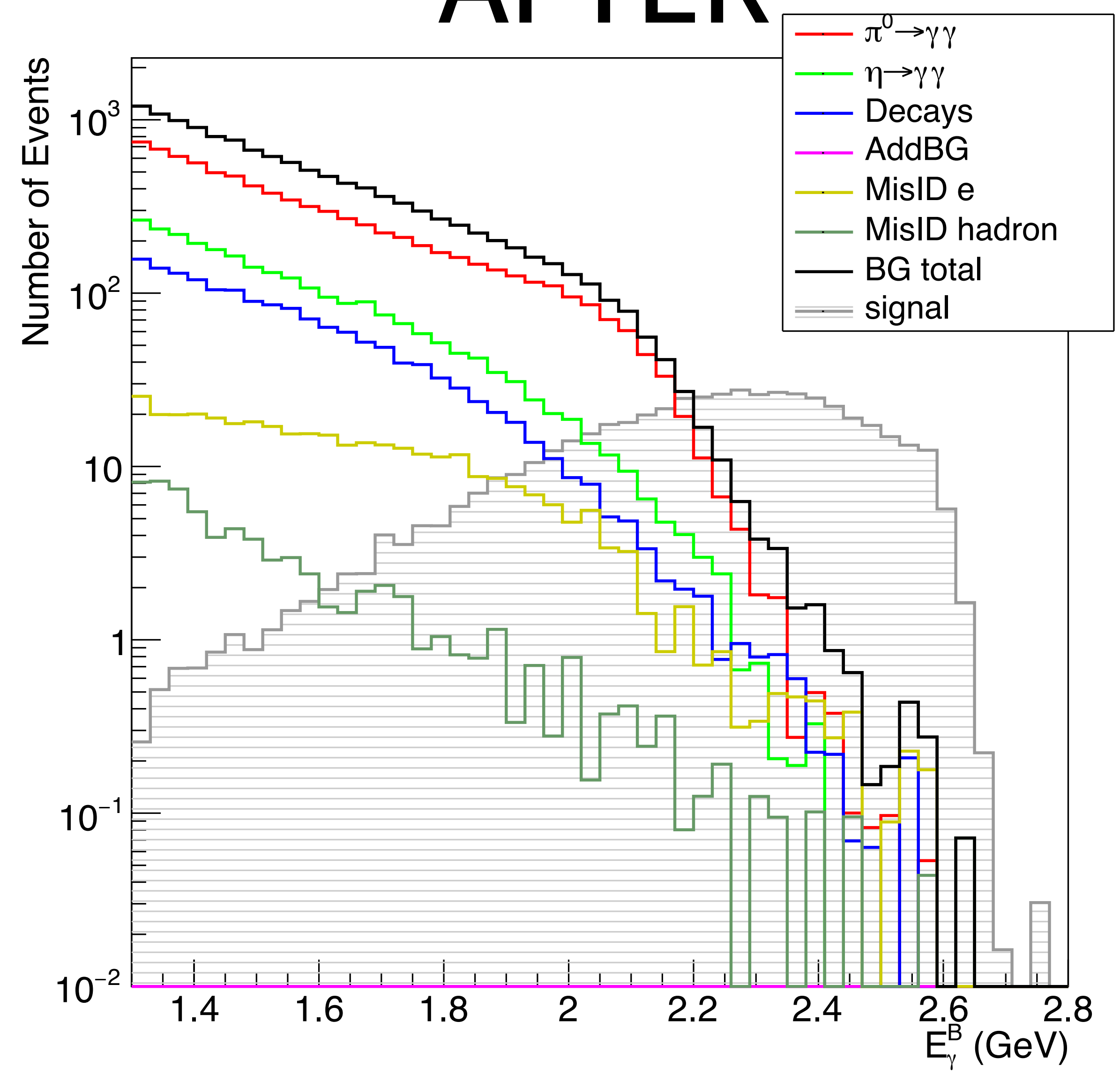
Angle btw. candidate gamma & the closest electron was tested to veto the events oriented by electron's emission. $e\rightarrow e\gamma$ events have a peak around $\cos\theta_e = 1$

Selection Criteria

BEFORE



AFTER



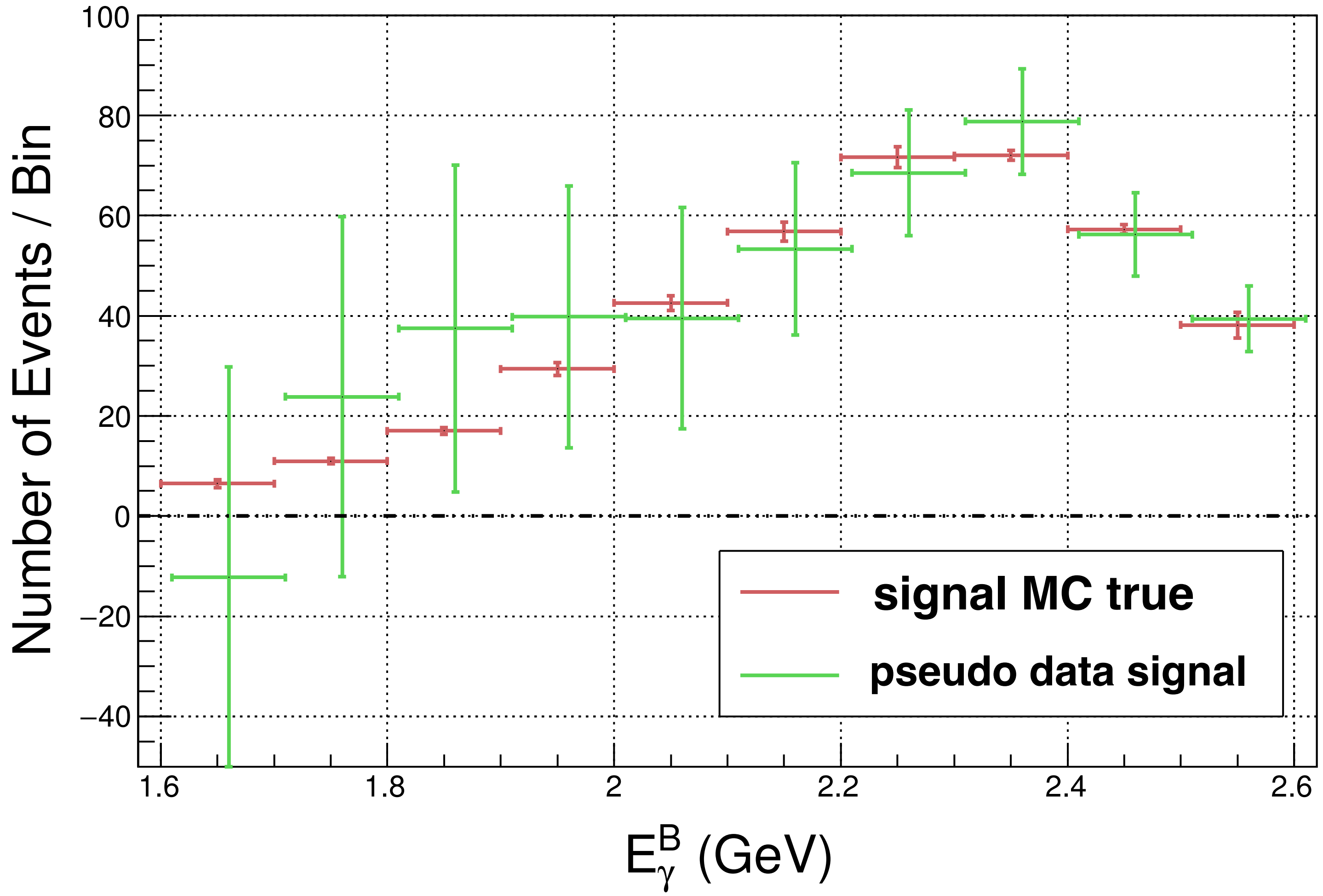
Each requirements were optimized to show the possible- highest significance in the target region, $1.8 < E_{\gamma} < 2.0$ GeV

Overall gaussian significance improved from 2.1 to 3.9

Many π^0 & η originated bkg still remaining

Validation

Before proceed, we validate the fitting and bkg subtraction method using a set of pseudo data events (toy MC)



Our methodology will do fine within the statistical errors of DATA.

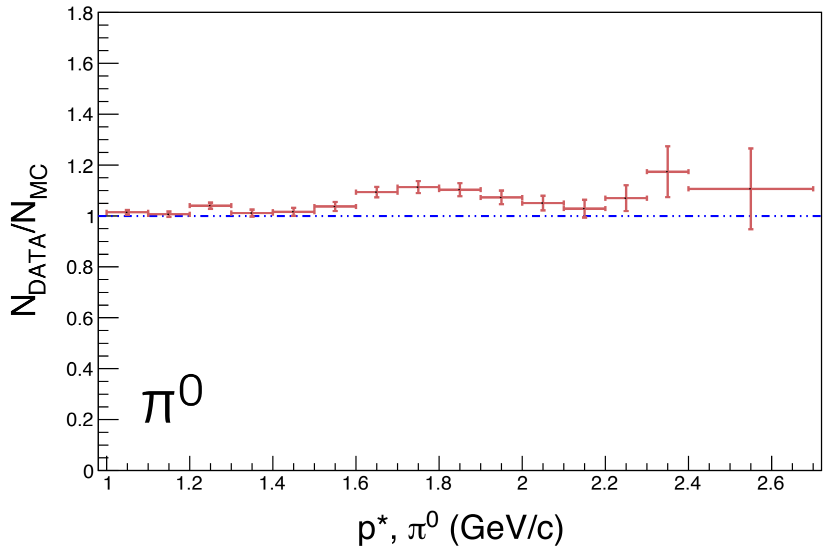
Background Summary

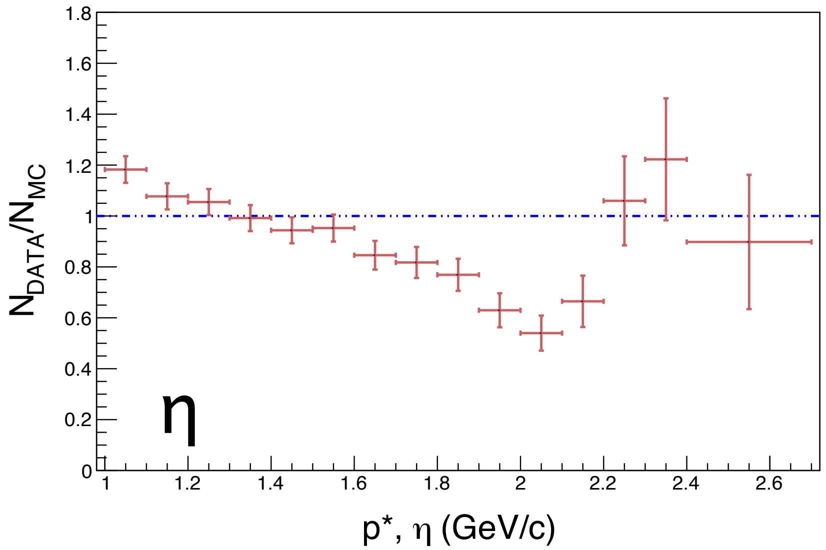
Samples	Percent in E_γ>1.8	1st order correction	Selection Criteria
Signal	16.9%	Not used in the measurement	
continuum	22.0%	Need to validate on using continuum MC	
$\pi^0 \to \gamma\gamma$	45.8%	Correction factors	Not studied yet
$\eta \to \gamma\gamma$	10.3%	Correction factors	Not studied yet
misID e	2.5%	Not corrected but 20% uncertainty on its yield will be assigned.	
misID had	0.3%	Small contribution, no correction but some conservative uncertainty on its yield will be assigned. (50% maybe?)	
Other decays	5.9%	Containing ω, J/Ψ, η', $X_c l \nu \gamma$ in majority and so many decays with small contributions, most of them are generated with well-measured BFs. So we don't do any corrections but an appropriate uncertainty will be assigned considering the combination.	

π^0/η Background Calibration

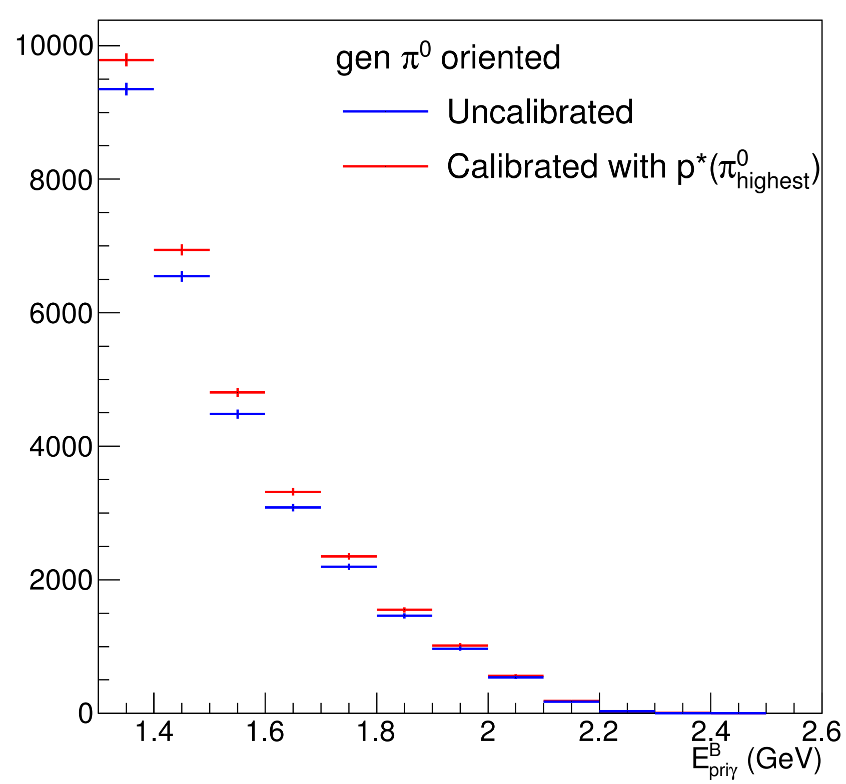
- To correct the absolute rate of π^0 & η background, the calibration factors are obtained using a large-sized set of M($\gamma\gamma$) control samples

Errors are only statistical at the moment

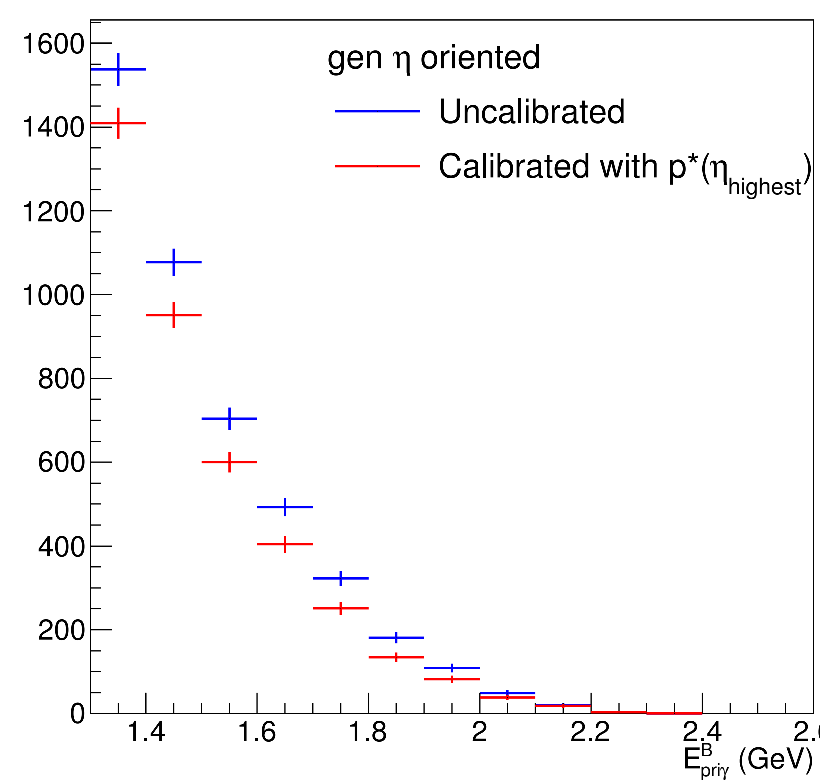




E_γ of π^0 bkg



E_γ of η bkg



Systematic Uncertainties

- Possible sources of systematic uncertainties
- Note most of them will be canceled out in asymmetry calculations

1. General
   1.1. Binning effect
   1.2. N_{BB} uncertainty
   1.3. Tagging efficiency bias

2. Signal Efficiency
   2.1. HFAG BF uncertainty
   2.2. BF($b \rightarrow d\gamma$) uncertainty
   2.3. Heavy quark parameters' uncertainties
   2.4. Extrapolation factor uncertainty
   2.5. High E photon detection rate
   2.6. SVD Matrix

3. Background Yield
   3.1. Correction factors
   3.2. Selection criteria

Working on this part!

Summary and Plan

- An radiational Electro Weak Penguin decay, $b \rightarrow s\gamma$ is being studied in Belle collaboration using hadronic decay. Selection variables are determined and studied.
- Valdiation on fitting and background subtraction method is done.
- The composition of background events are studied.
- 1st-order correction factors for π^0/η are obtained using a large control sample.
- Sources of systematic errors are surveyed.
- Need a further study on the background systematic uncertainty although temporary values are assigned.
- Need to improve optimization for a better measurement, A_{CP} on the selection criterias, signal region selection, etc.