Inclusive $B \rightarrow X_s \gamma$ on the Recoil of a Fully-Reconstructed B-Meson

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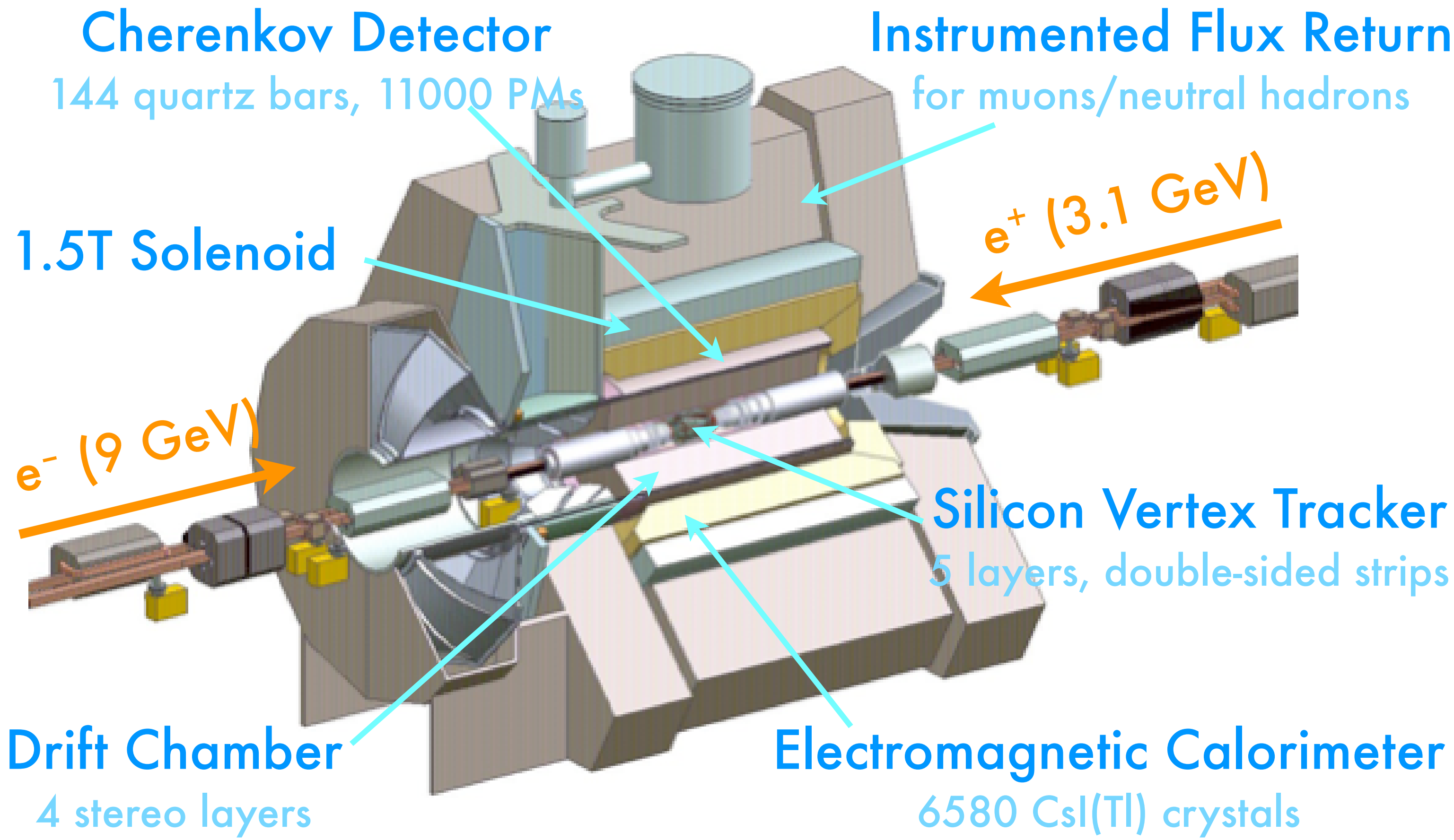
BaBar Collaboration

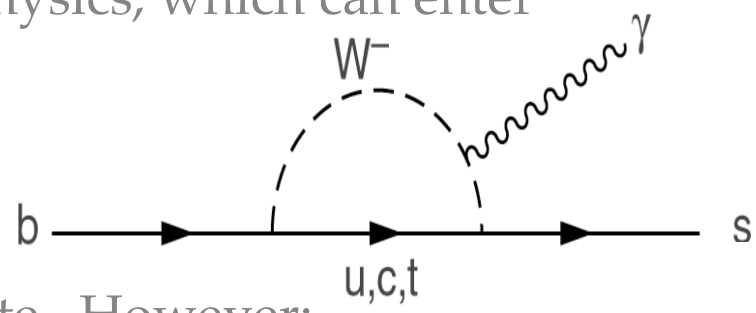
The Data

I use 232 million $B\bar{B}$ pairs recorded on the $\Upsilon(4S)$ resonance by the BaBar detector at the asymmetric e^+e^- B-factory PEP-II at SLAC



Studying $b \to s\gamma$

- Branching fraction is sensitive to new physics, which can enter through non-SM particles in the loop



- Can't measure the parton level decay rate. However:

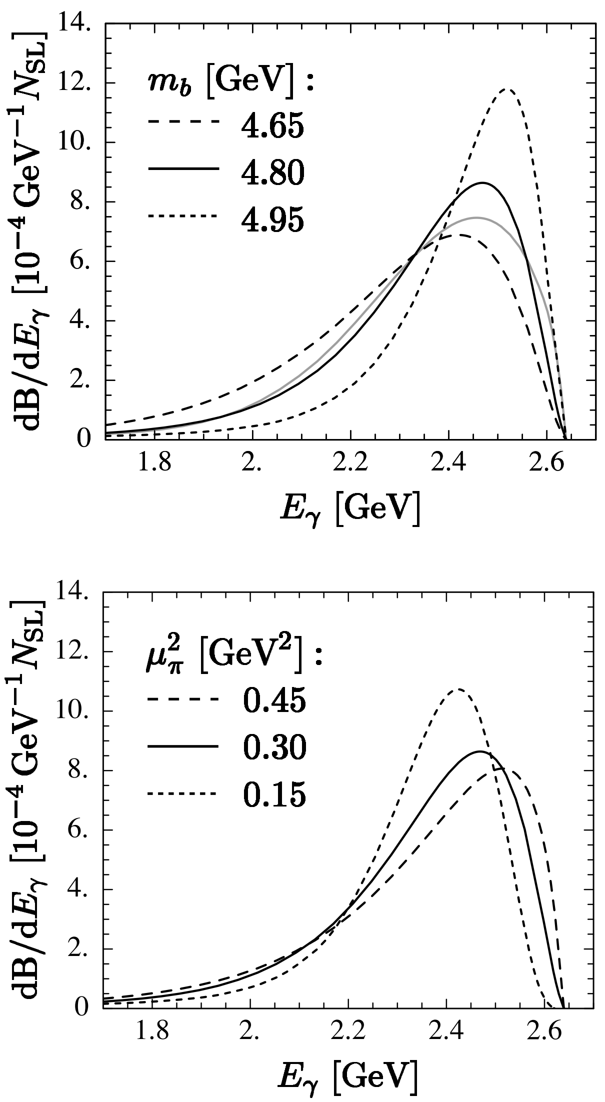
$$\text{HQET} \Rightarrow \Gamma(B \to X_s\gamma) = \Gamma(b \to s\gamma) + \Delta^{\text{nonpert}}$$

- Moments of photon energy spectrum are sensitive to Heavy Quark parameters m_b and μ_π^2
- Extraction of these with small errors leads to improvement of $|V_{ub}|$ error
- Standard Model prediction:

$$BR(B \to X_s\gamma) = (3.29 \pm 0.33) \times 10^{-4} \text{ (Kagan \& Neubert)}$$

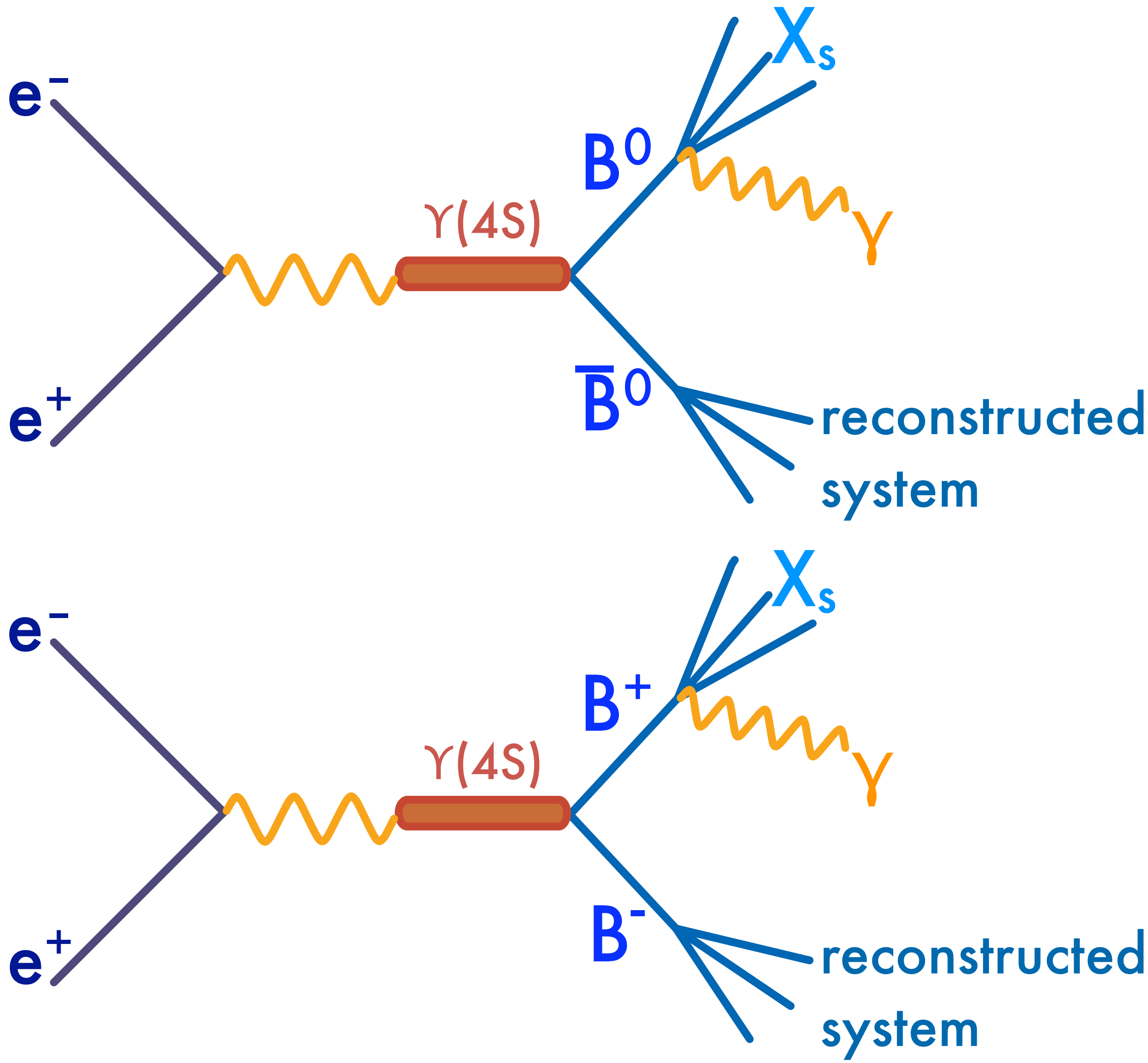
Modelling $B \to X_s\gamma$

- No strong force, would observe two monochromatic decay products, each with momentum $m_b/2$
- Strong force means that the s-quark fragments into a complicated spectrum of K* resonances
- b-quark has a Fermi momentum p_F, leading to a smearing of the photon spectrum
- $\langle E_\gamma \rangle \simeq m_b/2$, $\langle E_\gamma^2 \rangle$ is related to p_F



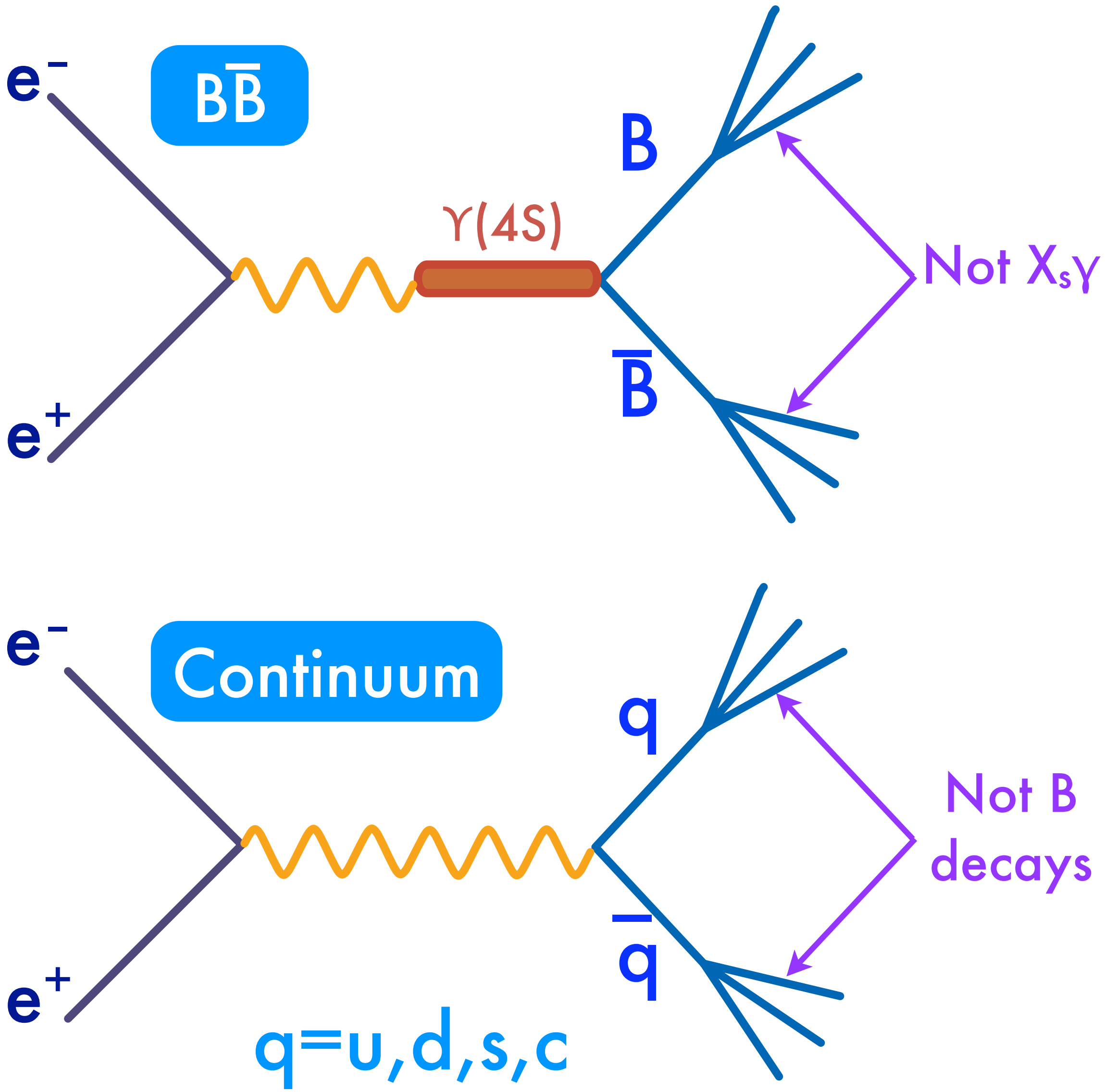
Kagan & Neubert `99

Signal Events



A fully reconstructed hadronic decay means that we can determine the B-meson flavour on the signal side

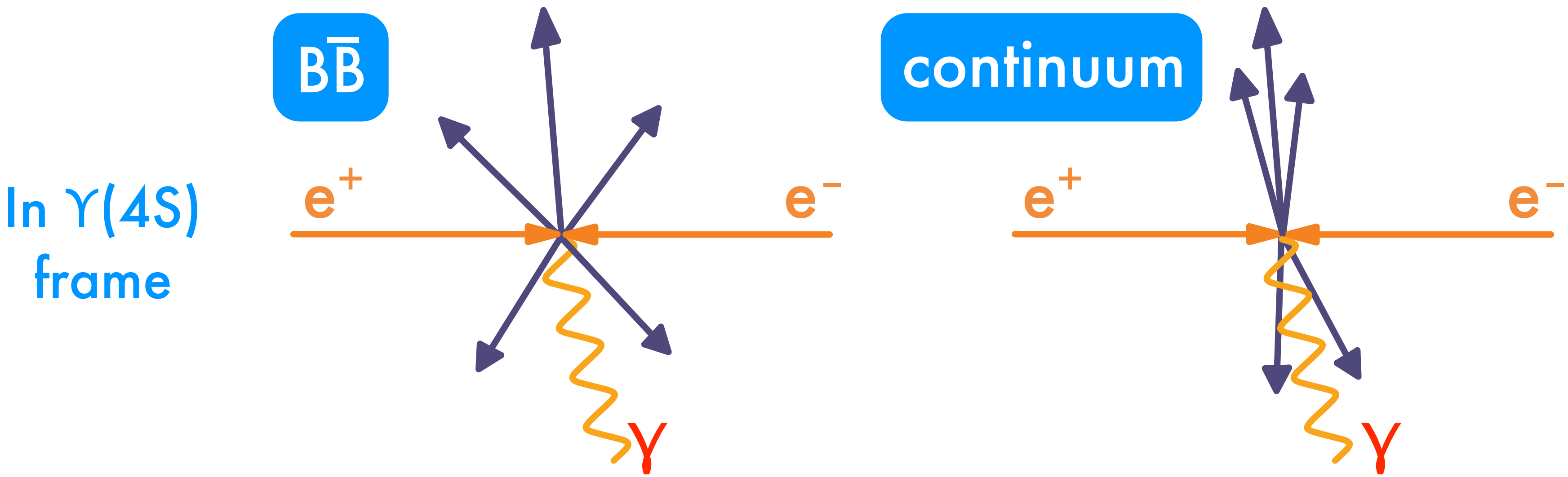
Background Events



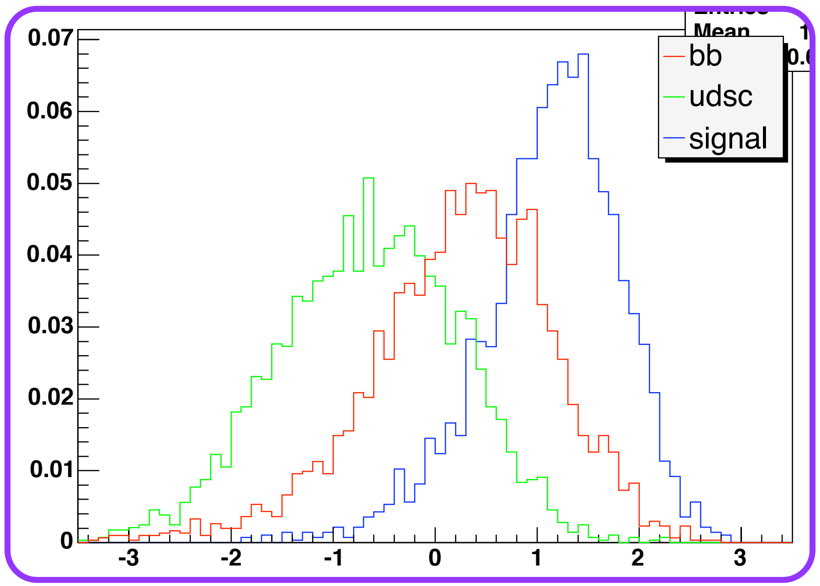
Production cross-section at $M(\Upsilon(4S))$ for $e^+e^- \rightarrow b\bar{b}$ is 1.05 nb, compared with 3.39 nb for $e^+e^- \rightarrow q\bar{q}$

Signal selection

Exploiting the Event Topography



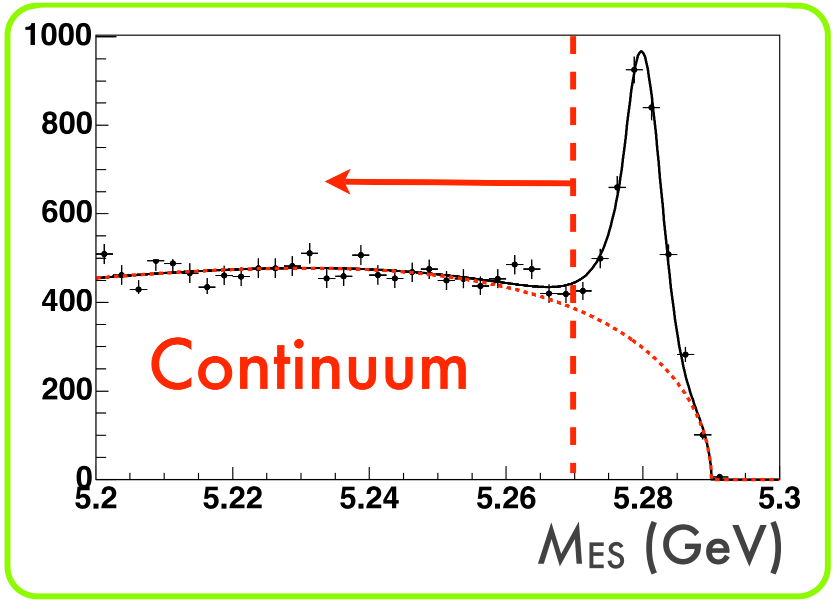
- We use a Fisher discriminant, a linear multi-dimensional cut, useful for correlated variables
- In this instance, use 15 variables that exploit difference in BB̄ and continuum event topology



B-Decay Kinematics

- Use $\Delta E = E_B^{*} - \sqrt{s}/2$ (should be close to zero for B-meson)
- Fit to beam energy-substituted mass (M_{ES}) to estimate and subtract remaining continuum background

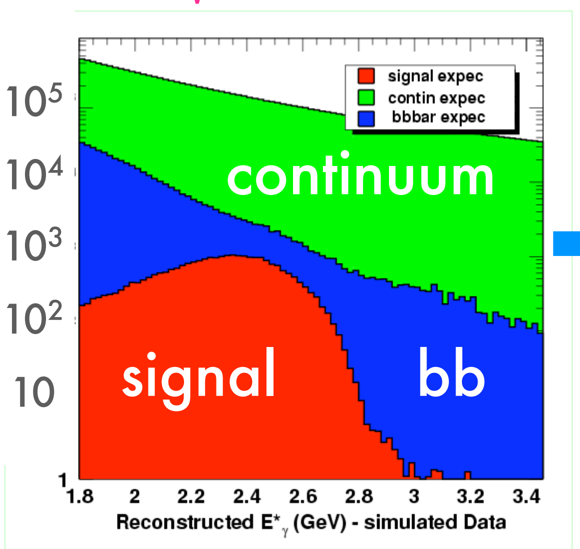
$$M_{ES} = \sqrt{s/4 - |\vec{p}^{*}_B|^2}$$



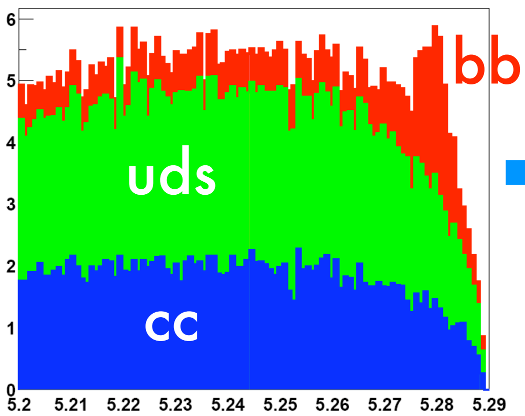
Photon Selection

- We select a single isolated photon in the energy range 1.3–2.7 GeV
- Principal source of background comes from $\pi^0 \to \gamma\gamma$ and $\eta \to \gamma\gamma$
  - Cut photon candidates with $M(\gamma_1\gamma_2) \sim M(\pi^0)$ or $M(\eta)$
- Still have π^0 background from $B \to D^* \rho^+$, $\rho^+ \to \pi^+\pi^0$, $\pi^0 \to \gamma\gamma$

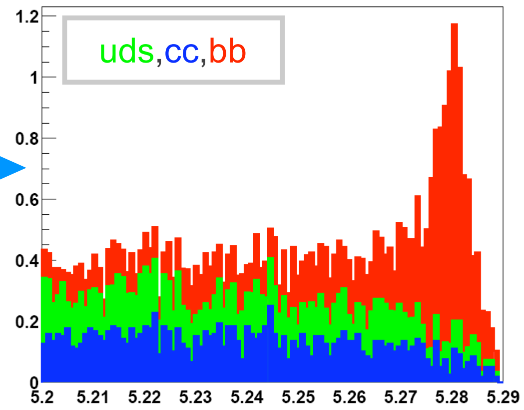
E_γ no cuts



M_{ES} photon selection



M_{ES} Fisher

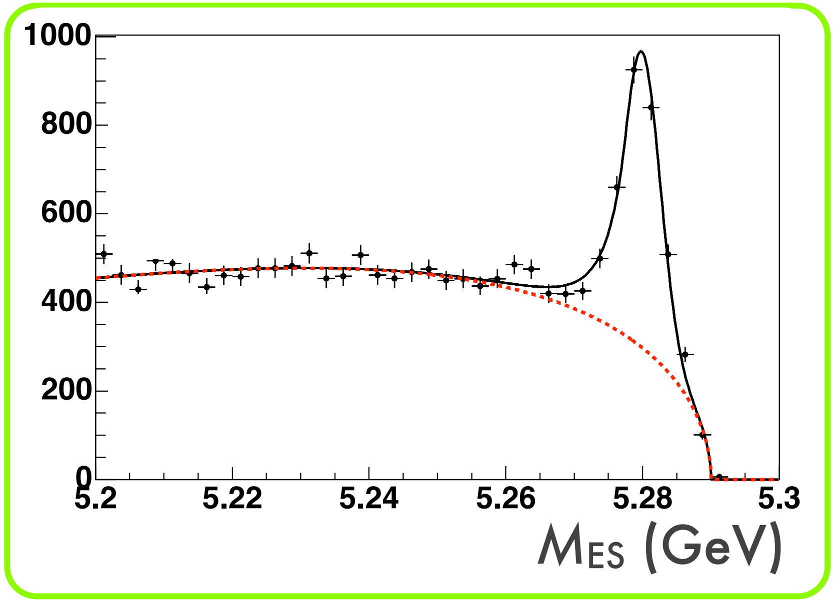


The Analysis on a Simulated Data Sample

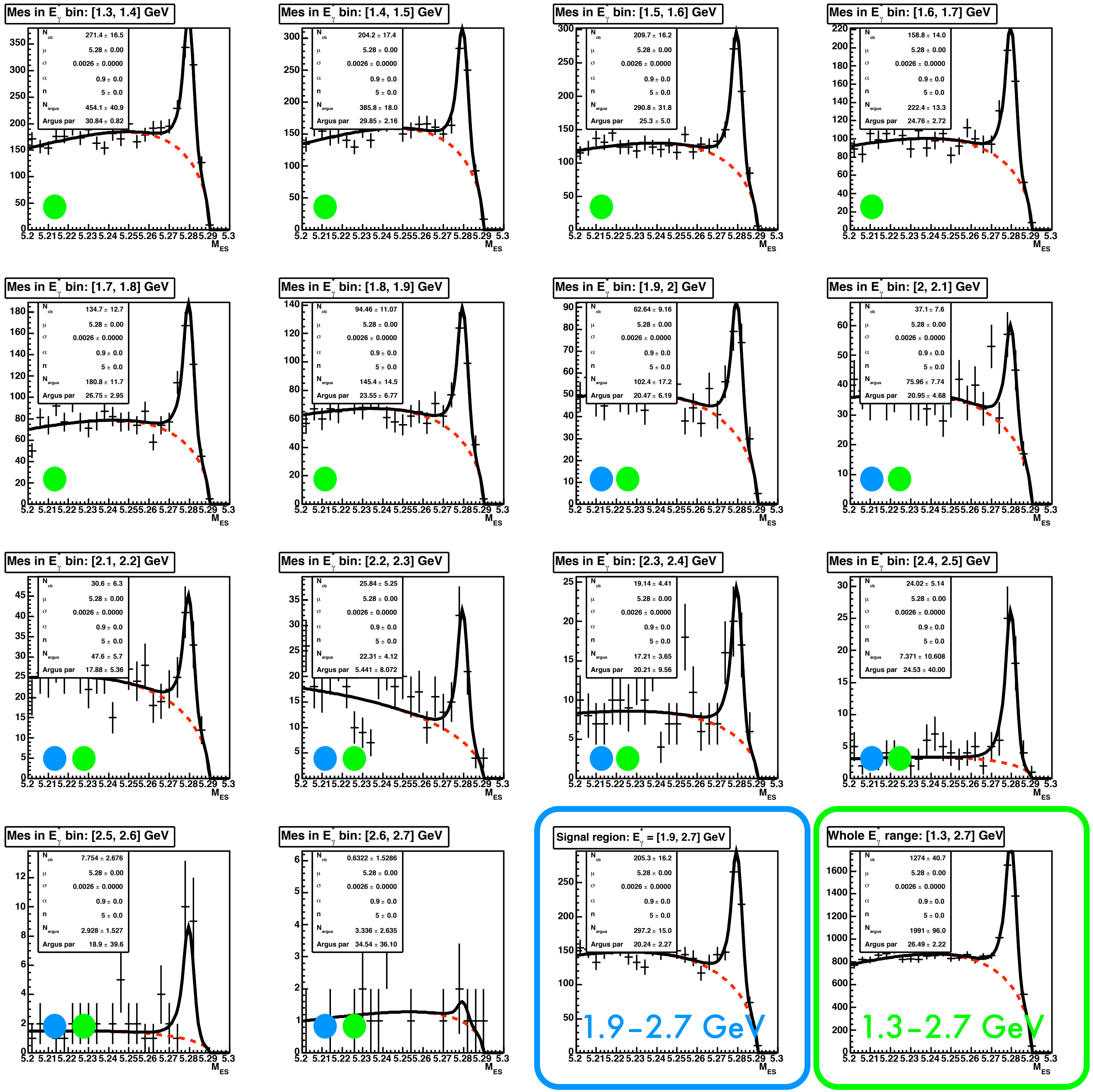
Outline of Analysis Concept

- Use a Fisher discriminant to distinguish between signal and continuum background ($u\bar{u}$, $d\bar{d}$, $s\bar{s}$, $c\bar{c}$)
- Select a high energetic photon on the un-reconstructed side to reduce background from other B decays
- Use a fit to the beam energy-substituted mass (M_{ES}) distribution of the reconstructed B to estimate and subtract remaining continuum
- The peaking $B\bar{B}$ background is estimated from MC
- Signal yield is extracted from binned χ^2 fit to E_γ distribution after selection

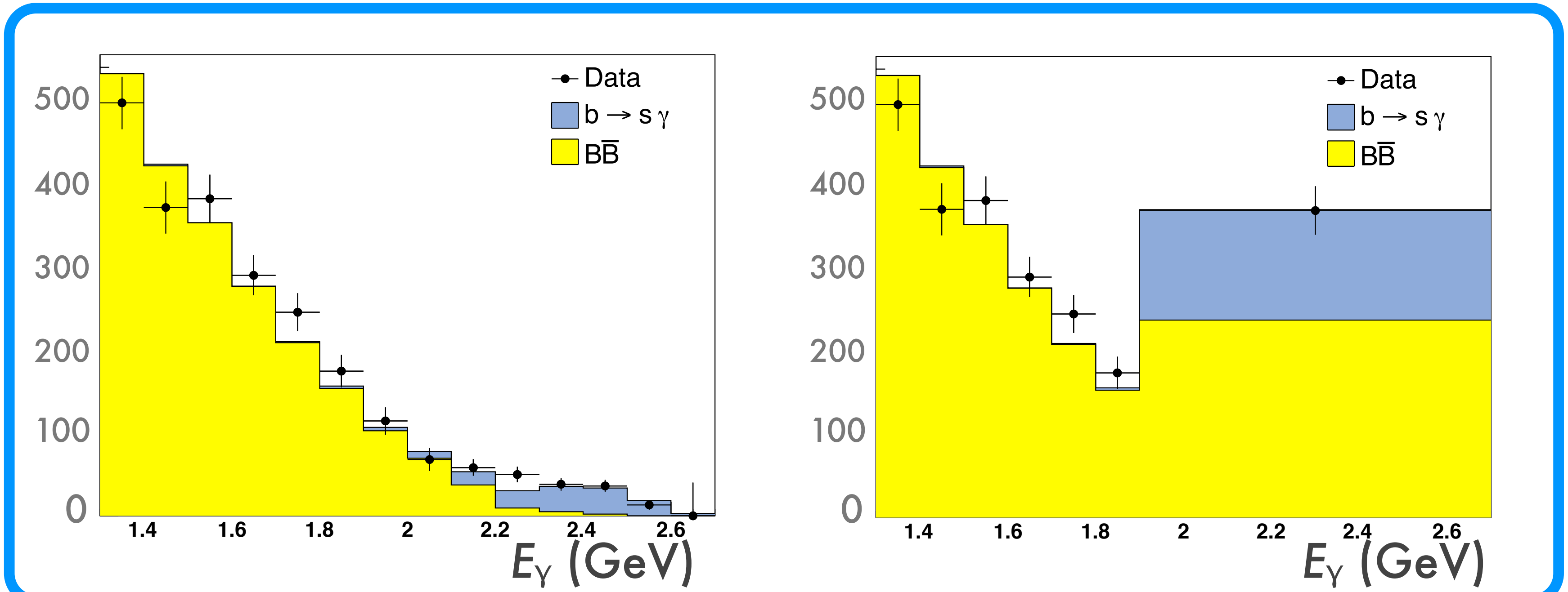
$$M_{ES} = \sqrt{s/4 - |\vec{p}^{\,*}_B|^2}$$



MES Plots for Simulated Data Equivalent



Results from Data Equivalent MC



- χ^2 fit to E_γ spectrum in region 1.3–2.7 GeV
- **Only one signal bin is used to measure the BR, as it is insensitive to shape**
- This is not the case when measuring the moments

Extraction of BR($B \to X_s \gamma$)

- Branching ratio is extracted using E_γ distribution:

$$\mathcal{B}(B \to X_s \gamma) = \frac{N^{sig}}{N^{B_{reco}} \varepsilon}$$

- N^{sig} is the signal contribution extracted from an M_{ES} fit with $E_\gamma > 1.9$ GeV, with BB background subtracted using χ^2 fit
- N^{Breco} is the number of reconstructed B-mesons extracted from an M_{ES} fit to data
- ε is an efficiency correction, taken from around ~800 fb^{-1} of MC
- From MC, we get BR($B \to X_s \gamma$) = $3.22 \pm 0.63 \times 10^{-4}$, compared with generator value of BR($B \to X_s \gamma$) = 3.29×10^{-4}

Conclusions and Outlook

- We can measure:
  - ➡ Branching Ratio for charged and neutral Bs together, as above, yielding on MC a value similar to the generator value
  - ➡ Branching Ratio for charged and neutral Bs separately
  - ➡ CP asymmetries
- There are still things to do:
  - Perhaps some changes to the fitting
  - Study systematics
- Measuring the spectrum moments will provide access to Standard Model parameters via HQET
- We hope to have a result by the Summer!

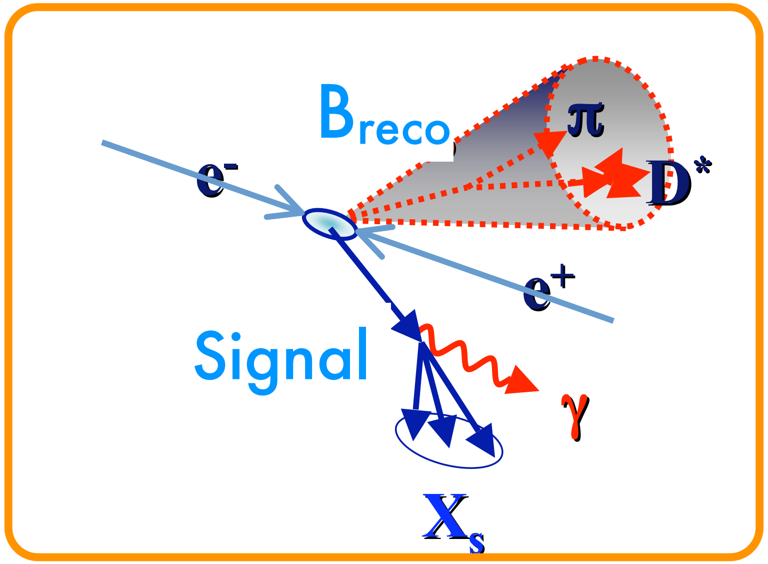
Backup slides

Selection Criteria

- One fully reconstructed B decay (B_{reco}) is required
- Minimum photon energy of 1.3 GeV
- Quality cut on lateral moment of shower, LAT < 0.45
  - Ranges from 0 to 1, small for EM showers, large for hadronic showers
- Photon bump isolation: Bump separation > 40 cm
- π^0 veto: 115 MeV / $c^2 < M_{\gamma\gamma} <$ 155 MeV / c^2
- η veto: 508 MeV / $c^2 < M_{\gamma\gamma} <$ 920 MeV / c^2
- ρ veto
  - 70% of the remaining π^0 background comes from $B \rightarrow D^*\rho$, $\rho \rightarrow \pi^0\pi^+$, $\pi^0 \rightarrow \gamma\gamma$
- Use of a Fisher discriminant (see later)

Advantages of using a Reconstructed B

- Reconstructed B kinematics are well known
- The E_γ spectrum is measured in the B rest frame
- Normalisation can be taken from number of reconstructed B-mesons before selection



- Purity of the sample can be adjusted by only selecting a sub-sample on the reconstructed B side
- Fully hadronic reconstruction of reconstructed B-meson allows tagging of B-meson charge and flavour, enabling separate measurements for charged and neutral Bs, as well as the measurement of A_{CP}
- Disadvantage: Small reconstruction efficiency ~0.4%

Extraction of N^{sig}

- Samples are divided into 0.1 GeV bins
- Each bin is fitted, and the combinatorial background is subtracted based on this
- N^{sig} is then extracted from a binned χ^2 fit:

$$\chi^2(C_s, C_b) = \sum_{i=0}^{\#bins} \left(\frac{N_i^{meas} - C_s N_i^{MC(b\to s\gamma)} - C_b N_i^{MC(bkgd)}}{\sqrt{(\delta N_i^{meas})^2 + (\delta N_i^{MC})^2}} \right)^2$$

- C_s and C_b are the normalisation of the the signal and background components respectively (free parameters)
- Last bin contains events with E_γ>1.9 GeV
- $N_{last}^{sig} = N_{last}^{meas} - C_b . N_{last}^{MC(bkgd)}$