Rare and Radiative B Decays:

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on behalf of the

BABAR Collaboration.

Moriond Electroweak 2002

Radiative Penguins and Rare Decays

top CKM couplings:

- Ratio $|V_{td}/V_{ts}|$:
- $B \to \rho\gamma$
- $B \to K^*\gamma$

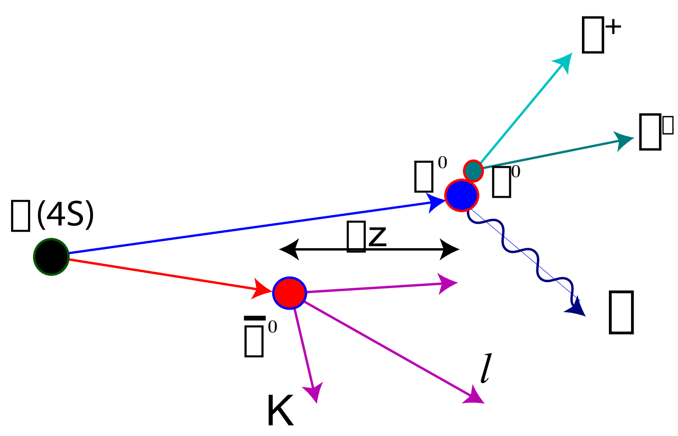
Look for new physics:

- Rare decays: $B^0 \to e^+e^-$.
- Direct CP Violation: $B \to K^*\gamma$

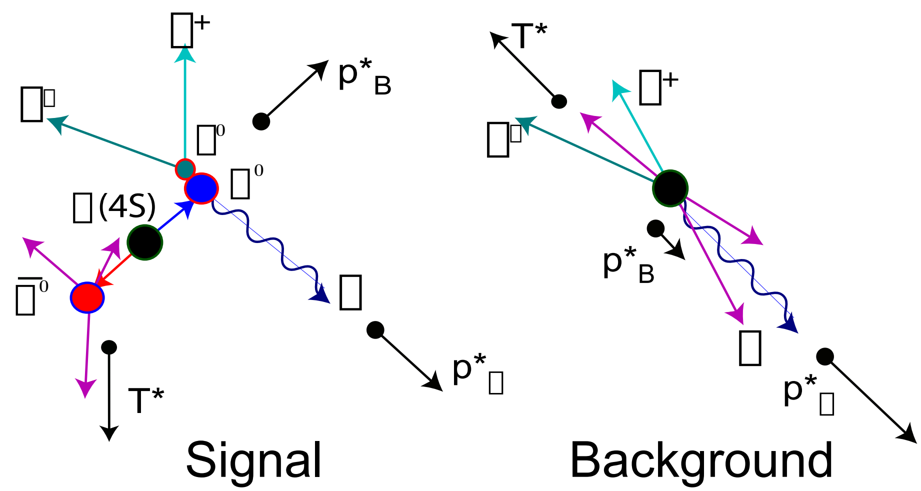
Run I: $22.7\times 10^6 B\overline{B}$ ($B \to K^*\gamma$)
Run I+II: $62.7 \times 10^6 B\overline{B}$

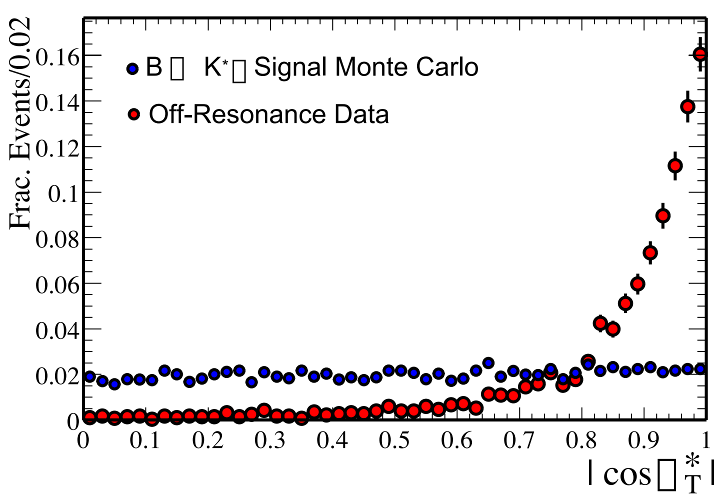
Background Suppression

Lab Frame

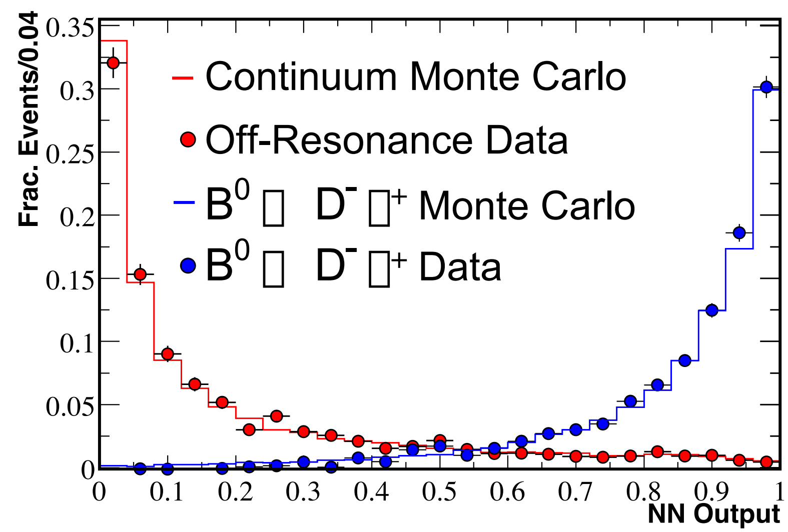


CM Frame





Cut on Event Shape



Fisher/Neural Network

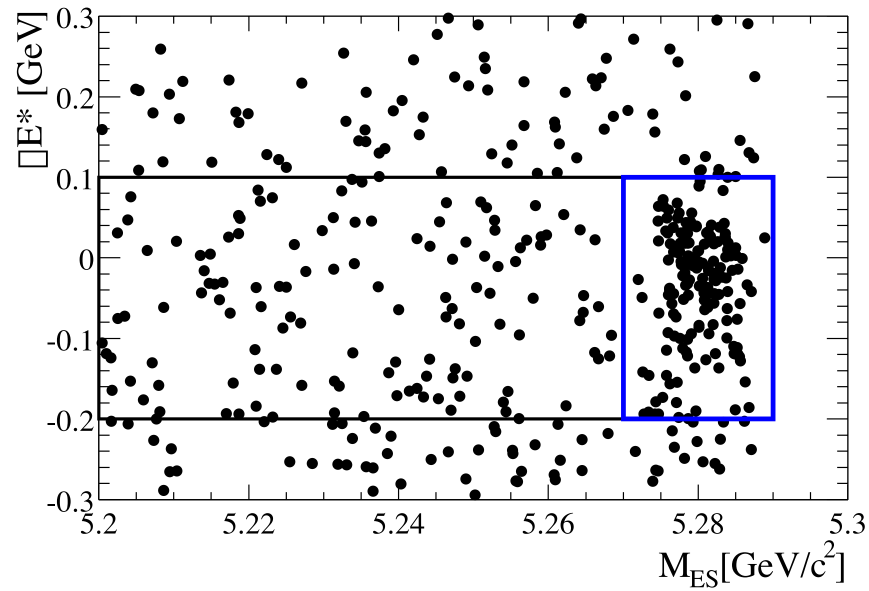
B Kinematics and Signal Extraction

Reconstruct B Candidate and use beam energy to define:

- $\Delta E = E_B^* - \sqrt{s}/2$
- $m_{\rm ES} = \sqrt{s/4 - {p_B^*}^2}$

* denotes CMS.

Analysis-dependent variations.



ΔE vs. $m_{\rm ES}$ for $B \to K^*\gamma$

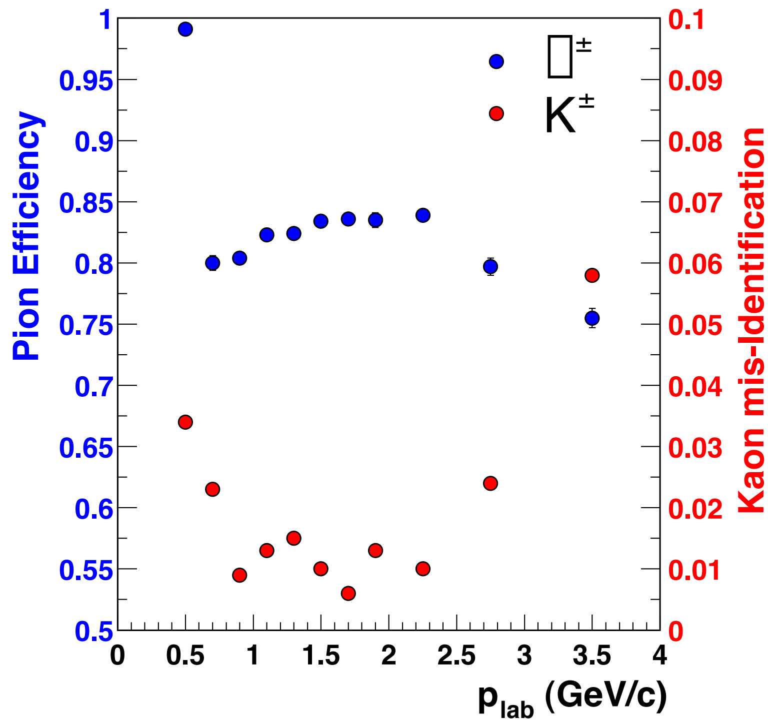
Blind Analyses:

- Signal Box in $m_{\rm ES}$, ΔE blinded.
- Optimize selection and cuts.
- Background estimates checked in sidebands.

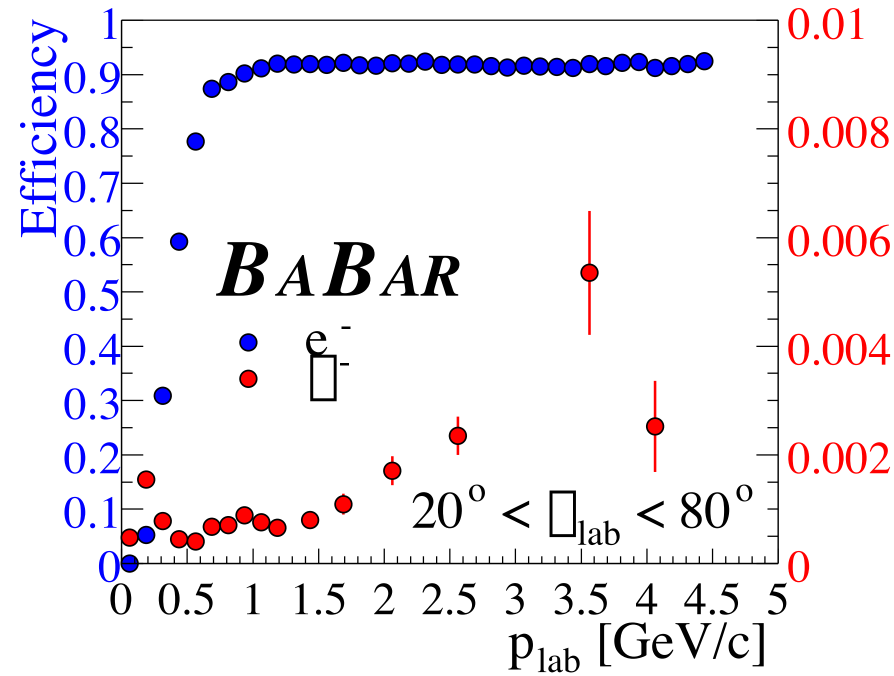
Signal Extraction:

- Fit $m_{\rm ES}$ to signal and background components.
- Add variables for multivariate fit.
- Cross-check with cut & count analysis.

Particle Identification:



$B \to \rho\gamma$: π ID to suppress $B \to K^*\gamma$.



$B^0 \to e^+e^-$: electron ID from $1 - 5\,\mathrm{GeV}/c$

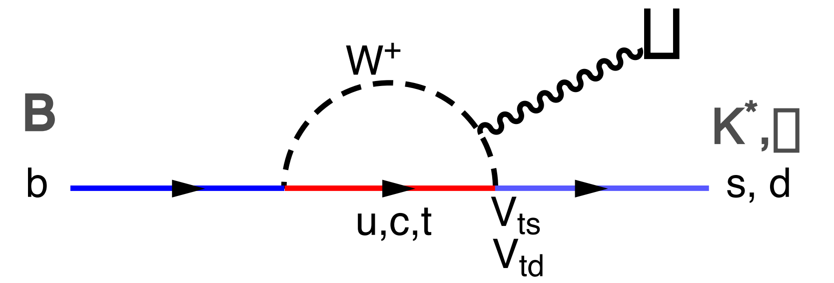
Good particle ID important in Analyses.

- Reduces combinatoric background (continuum and $B\overline{B}$)
- Reduces some dangerous B backgrounds.

The Radiative Decays $B \to (\rho/K^*)\ \gamma$

Probe CKM: $V_{td},\ V_{ts}$

- $\approx 10\%$ inclusive rate predictions
- Exclusive decay rates difficult.



Electroweak Penguin Transition

Predictions:

- $|V_{td}/V_{ts}|$ with 10% uncertainty.
- $B \to K^*\gamma$:
  Direct CP Violation $< 0.5\%$
- Isospin breaking

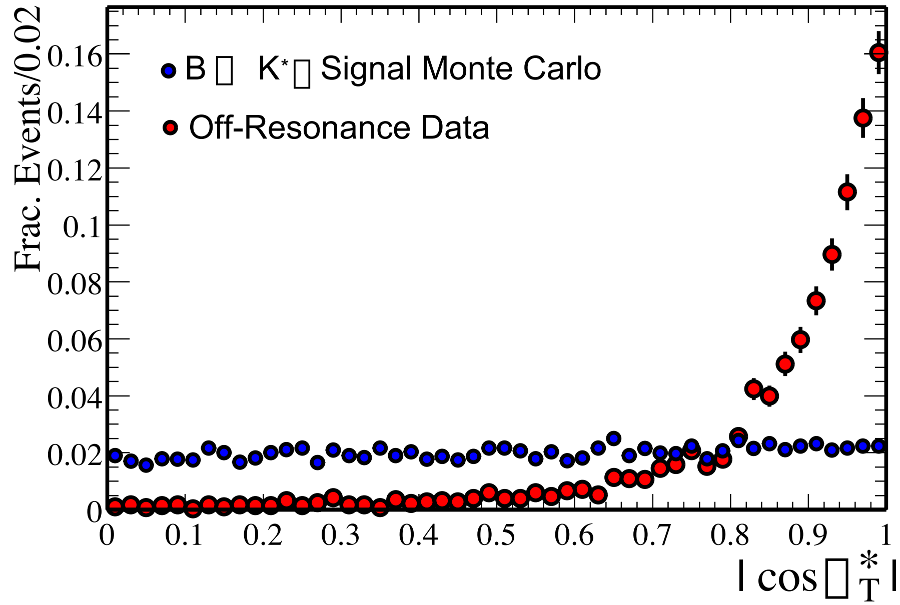
- Interference from new physics:
  Up to 20% CP Violation in
  $B \to K^*\gamma$
  (Kagan & Neubert)

$$\frac{\mathcal{B}[B \to \rho\gamma]}{\mathcal{B}[B \to K^*\gamma]} = S_\rho \left| \frac{V_{td}}{V_{ts}} \right|^2 \left[\frac{1 - m_\rho^2/M^2}{1 - m_{K^*}^2/M^2} \right]^3 \zeta^2 [1 + \Delta R(\rho/K^*)]$$

Paper/Exp $\mathcal{B}/10^{-5}$	$B^0 \to K^{*0}\gamma$	$B^+ \to K^{*+}\gamma$	$B^0 \to \rho^0\gamma$	$B^+ \to \rho^+\gamma$
Bosch & Buchalla	7.1 ± 2.5	7.5 ± 2.5		0.16 ± 0.05
Beneke et. al.	7.9 ± 3.5	7.9 ± 3.5		
Ali & Parkhomenko	7.2 ± 2.7	7.2 ± 2.7	0.049 ± 0.017	0.085 ± 0.30
CLEO	$4.55^{+0.72}_{-0.68} \pm 0.34$	$3.76^{+0.89}_{-0.83} \pm 0.28$	< 1.7	< 1.3
BELLE	$4.96 \pm 0.67 \pm 0.45$	$3.89 \pm 0.93 \pm 0.41$	< 1.06	< 0.99

$B \to K^*\gamma$: the Analysis

1. Photon Selection
   - Veto π^0, η
   - Lateral profile
   - Isolation (25 cm)
2. Reconstruct K^*:
   - $K^{*0} \to K^+\pi^-,\ K^0_S\pi^0$
   - $K^{*+} \to K^+\pi^0,\ K^0_S\pi^+$
3. Suppress continuum.



- Kaon PID reduces combinatoric background
- Select candidates: $\Delta E = [-0.200, 0.100]\,\mathrm{GeV}\ (K^+\pi^-,\ K^0_S\pi^+)$
  $\Delta E = [-0.225, 0.125]\,\mathrm{GeV}\ (K^+\pi^0,\ K^0_S\pi^0)$
- Fit m_{ES} to extract signal yield. Look for CP Violation

$B \to K^*\gamma$: **Run I** $(22.7 \times 10^6 B\bar{B})$ **Results**

Yields from m_{ES} Fit

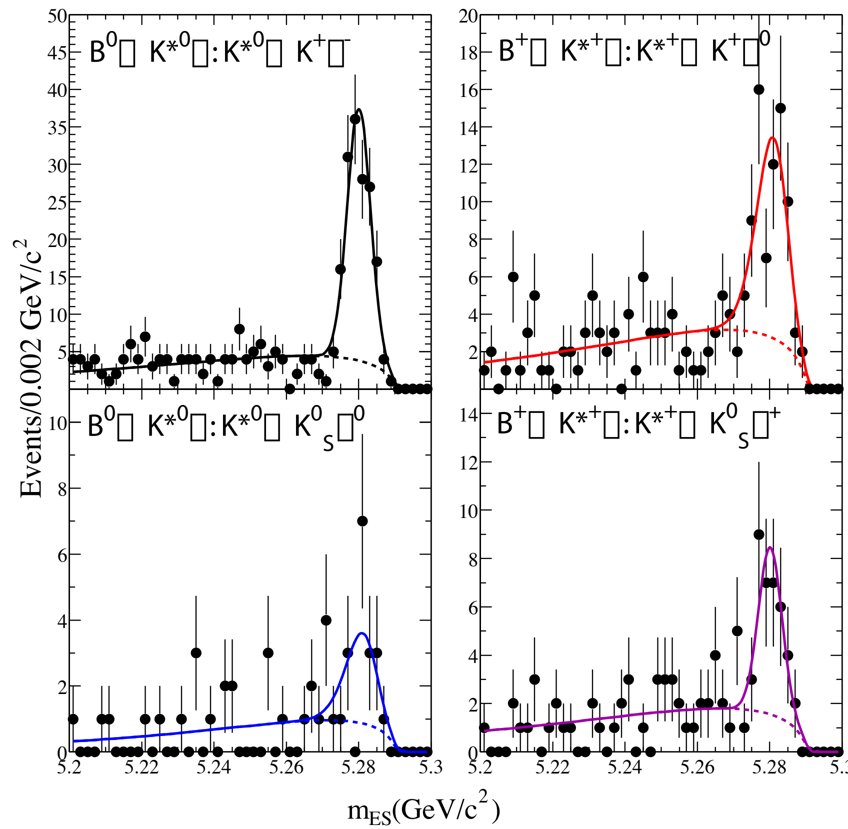
Mode	Efficiency (%)	Yield
$K^{*0} \to K^+\pi^-$ †	14.0	134.7 ± 13.3
$K^{*0} \to K^0_S\pi^0$	1.4	13.4 ± 5.6
$K^{*+} \to K^+\pi^0$ †	4.3	53.8 ± 10.4
$K^{*+} \to K^0_S\pi^+$ †	3.9	26.2 ± 6.6

† Modes are used for CP Violation

$$A_{CP} = \frac{\Gamma(\bar{B}\to\bar{K}^*\gamma)-\Gamma(B\to K^*\gamma)}{\Gamma(\bar{B}\to\bar{K}^*\gamma)+\Gamma(B\to K^*\gamma)}$$

CLEO: $A_{CP} = 0.08 \pm 0.13 \pm 0.03$

BELLE: $A_{CP} = 0.02 \pm 0.11 \pm 0.01$

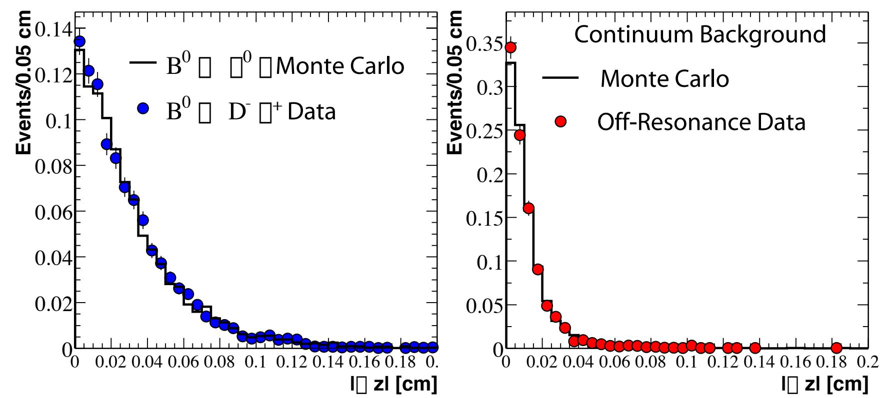


- $\mathcal{B}[B^0 \to K^{*0}\gamma] = [4.23 \pm 0.40 \pm 0.22] \times 10^{-5}$
- $\mathcal{B}[B^+ \to K^{*+}\gamma] = [3.83 \pm 0.62 \pm 0.22] \times 10^{-5}$
- $A_{CP} = -0.044 \pm 0.076 \pm 0.012$, $[-0.170 < A_{CP} < 0.082]$ 90% CL

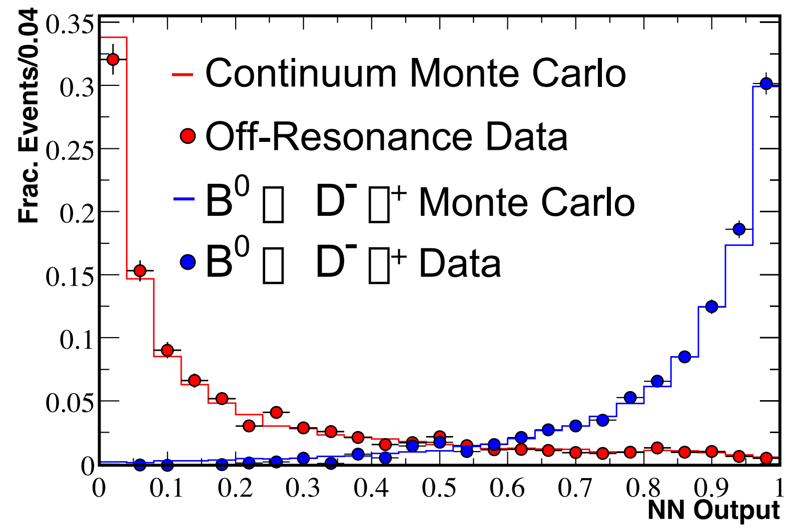
To appear in Phys. Rev. Letters. Run II analysis in the works.

Search for $B \to \rho\gamma$

- The challenge: Similar to $B \to K^*\gamma$ but:
  1. $\mathcal{B}[B \to K^*\gamma] \approx 50 \times \mathcal{B}[B \to \rho\gamma]$
  2. More combinatoric background.
  3. Wider resonance width $(3\times)$
  4. $B \to K^*\gamma$, $B^+ \to \rho^+\pi^0$ background.
- The strategy: new techniques
  1. Vertex separation
  2. Flavor tagging
  3. More topology variables: $\cos\Theta_T$, $\cos\Theta_B$, $\cos\Theta_H$, Cones, R_2'
  4. NN exploits correlations.
  5. Multivariate ML Analysis



Δz Signal vs. Background



NN Signal vs. Background

- NN input/output cross-checked with data control samples.
- $2\times$ improvement in background suppression.

$B \to \rho\gamma$: **the Analysis**

Reconstruction

- Photon selection $= B \to K^*\gamma$.
- $B \to K^*\gamma$ background
  π selection:
  80% π eff., 1% K mis-id.
- $B^+ \to \rho^+\pi^0$ background
  Helicity of ρ candidate:
  V/γ vs V/PS: $\sin^2\Theta_H$ vs. $\cos^2\Theta_H$
  $\to |\cos\Theta_H| < 0.6$

Expectations: ($\mathcal{B}[B^0 \to \rho^0\gamma] = 1 \times 10^{-6}$)

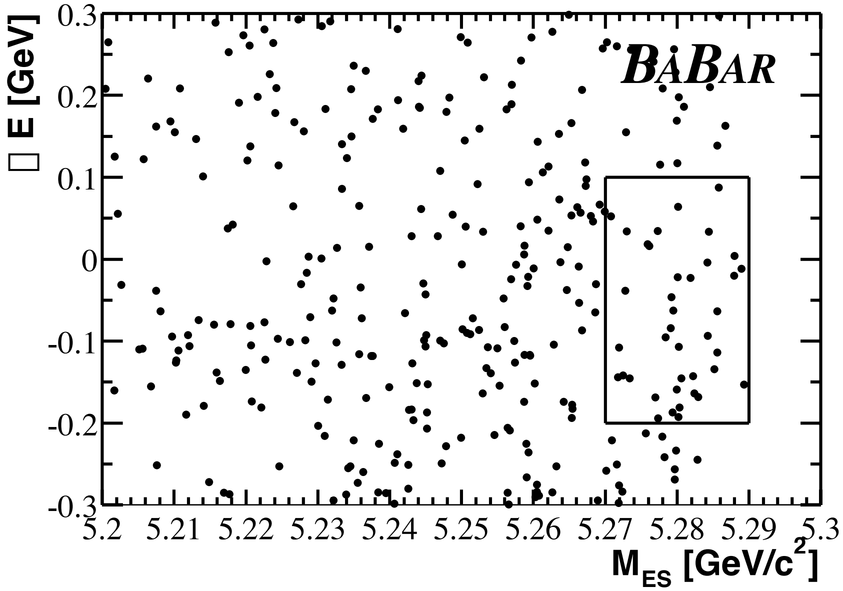
- Optimize NN cut for $S^2/(S+B)$
- $B^0 \to \rho^0\gamma$: ≈ 8 Events
- $B^+ \to \rho^+\gamma$: ≈ 11 Events

Signal Extraction via ML Fit:

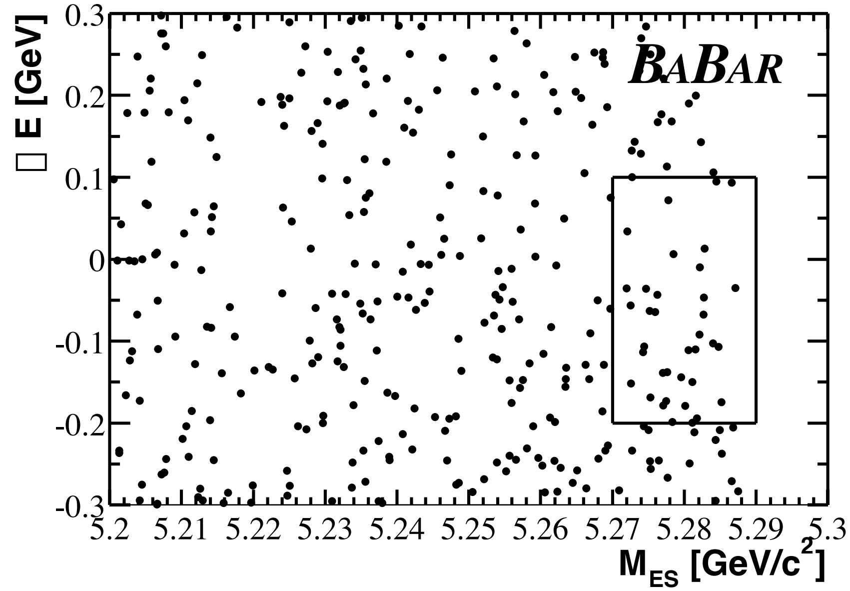
- m_{ES} (Mass of B candidate)
- ΔE ($E_B - \frac{1}{2}\sqrt{s}$)
- $M_{\pi\pi}$ (resonance mass);

- Background parameters float in fit (except $M_{\pi\pi}$ resonant fraction).
- Signal PDFs determined from data $B \to K^*\gamma$.
- Systematics (15%):
  Background resonant fraction, NN cut, B backgrounds

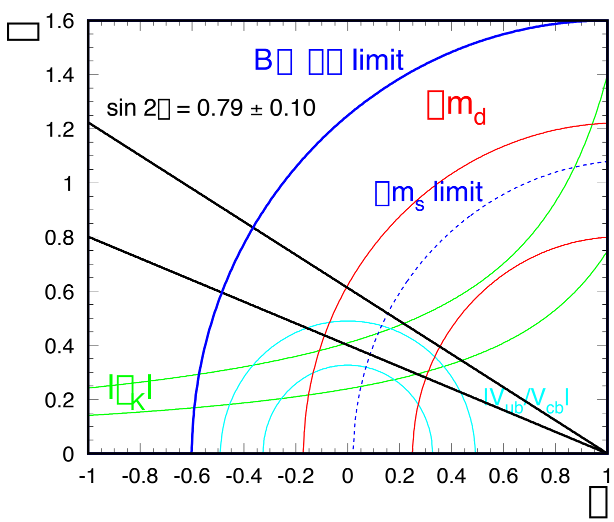
$B \to \rho\gamma$: Unblinded Run I/II Results



$B^0 \to \rho^0\gamma$: 3.1 ± 4.2 Events



$B^+ \to \rho^+\gamma$: 4.6 ± 5.8 Events

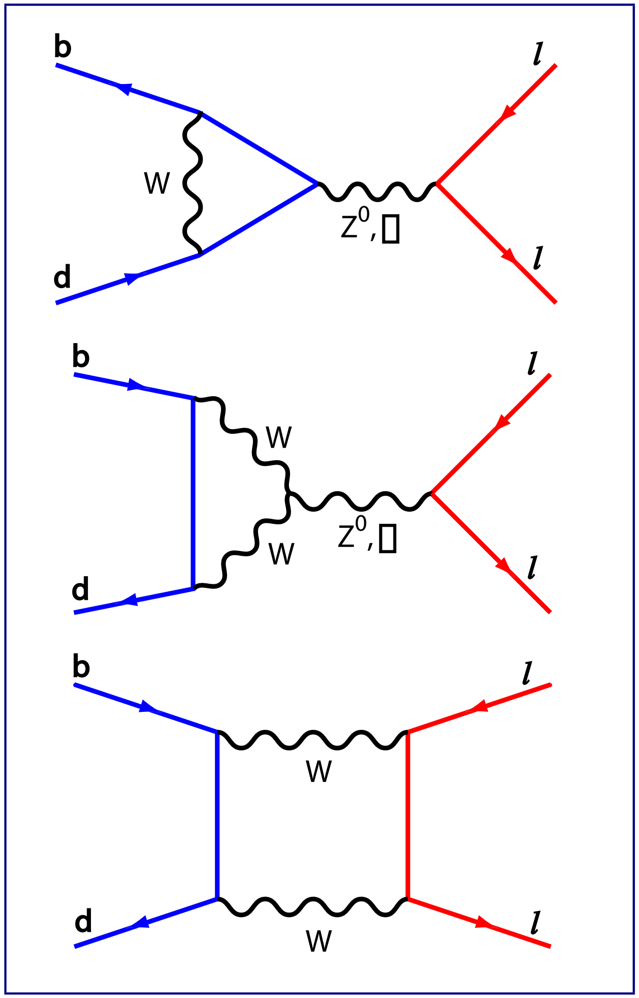


$|V_{td}/V_{ts}|$ Constraint: no theory errors.

Preliminary 90% CL Limits:

- $\mathcal{B}[B^0 \to \rho^0\gamma] < 1.5 \times 10^{-6}$
- $\mathcal{B}[B^+ \to \rho^+\gamma] < 2.8 \times 10^{-6}$

$B^0 \to e^+e^-$: Run I/II



Highly Suppressed in the Standard Model

- Needs $b \to d$ transition
- Quark annihilation $(f_B/M_B)^2$
- Helicity suppression for $B^0 \to e^+e^-$

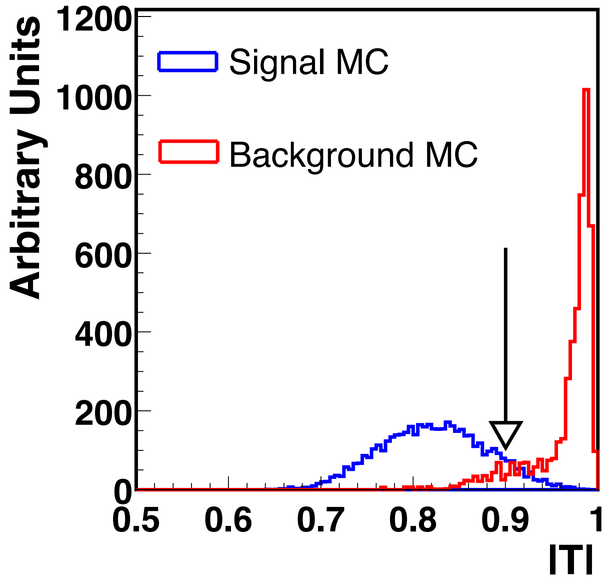
New physics scenerios enhance by orders of magnitude:

- R-parity violating SUSY
- Leptoquarks
- etc.

SM Predictions and Current Experimental Limits:

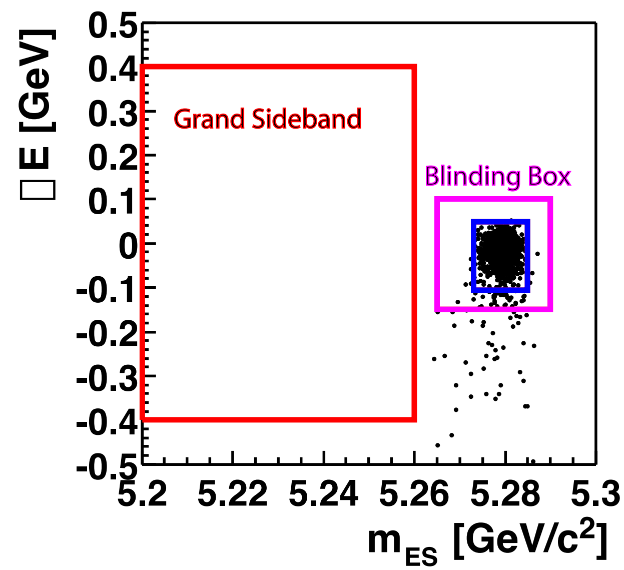
Standard Model	CLEO	BELLE
1.9×10^{-15}	$< 8.3 \times 10^{-7}$(0)	$< 6.3 \times 10^{-7}$(1)

$B^0 \to e^+e^-$: the Analysis



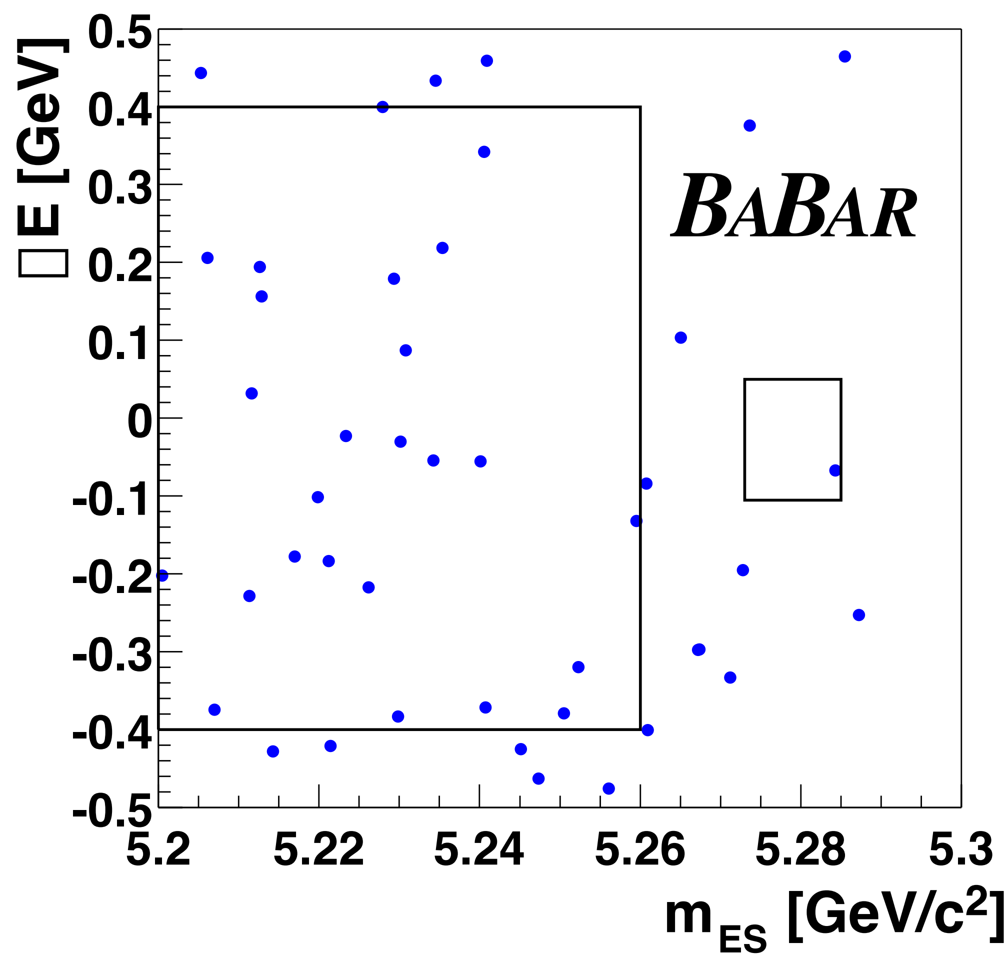
1. Event multiplicity (tracks and photons).
2. Electron ID
   - $> 90\%$ e efficiency, $\mathcal{O}(10^{-3})$ π mis-Id.
3. Suppress with Event shape cuts
   - Thrust $|T| < 0.9$, $\cos\Theta_T < 0.84$

- Cuts optimized for Upper Limit.
- Remaining background: real electrons
  1. semileptonic decays from $c\bar{c}$ continuum.
  2. Two-photon physics.
- Signal and blinding box defined.



Signal Monte Carlo

$B^0 \to e^+e^-$: Run I/II Unblinded Result



Background Estimate:

- Bkg.from Data
- Checked with Monte Carlo
- Expect: 0.60 ± 0.24

Result:

One event in Signal Box

$B \to \mu\mu$, $B \to e\mu$ in the works

Preliminary 90% CL Limit:

$\mathcal{B}[B^0 \to e^+e^-] < 3.3 \times 10^{-7}$

Conclusions

Preliminary Rare B decay results with $62.7 \times 10^6 B\overline{B}$:

Measurement of $B \to K^* \gamma$ in Run I.

$\mathcal{B}[B^0 \to K^{*0}\gamma] = [4.23 \pm 0.40 \pm 0.22] \times 10^{-5}$

$\mathcal{B}[B^+ \to K^{*+}\gamma] = [3.83 \pm 0.62 \pm 0.22] \times 10^{-5}$

No significant signal for $B \to \rho\gamma$

Preliminary 90% Confidence Level Limits:

$B^0 \to \rho^0\gamma < 1.5 \times 10^{-6}$, $B^+ \to \rho^+\gamma < 2.8 \times 10^{-6}$

No significant signal for $B^0 \to e^+e^-$:

Preliminary 90% Confidence Level Limit:

$B^0 \to e^+e^- < 3.3 \times 10^{-7}$

Many more results coming soon!