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FCNC Decays of B Mesons

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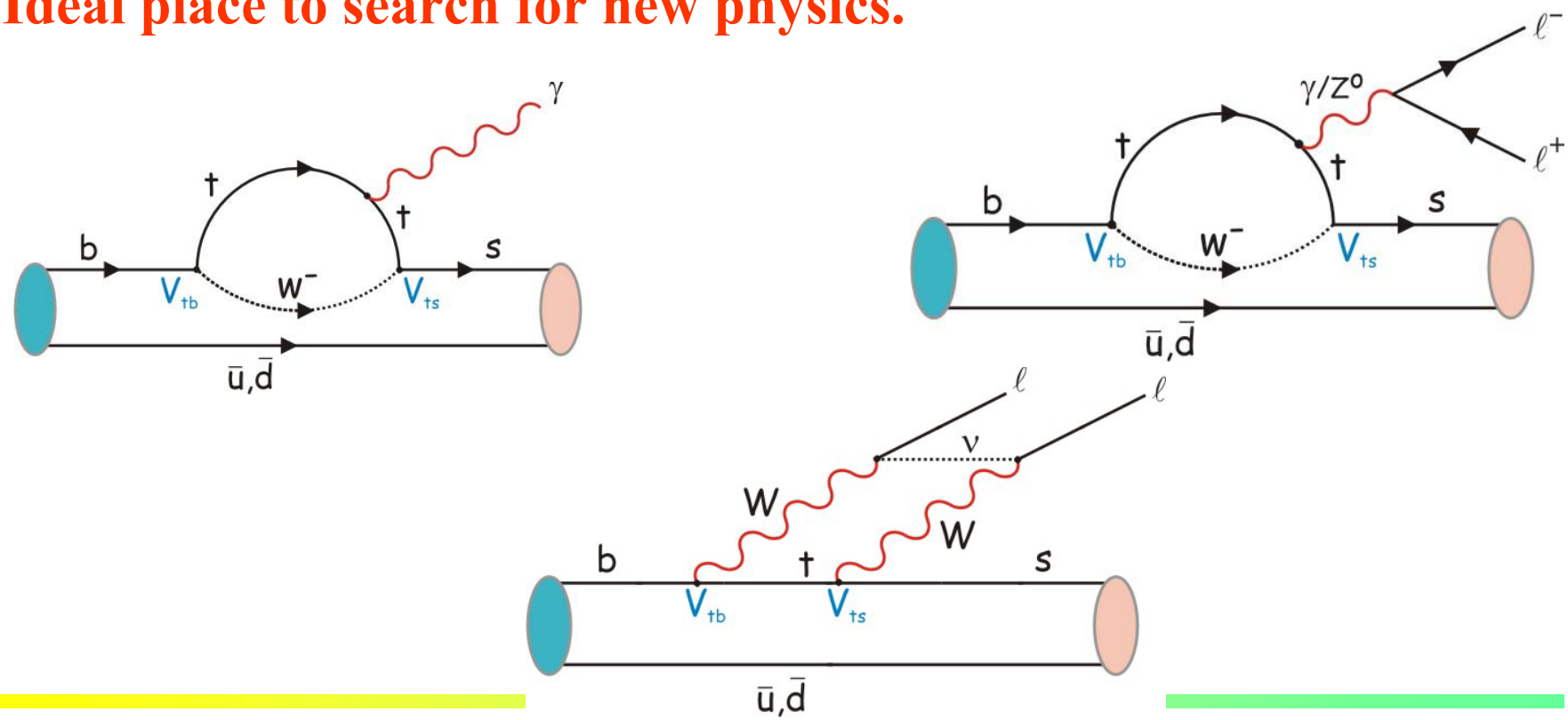
For the Belle Collaboration

Contents

Motivation

Flavour changing neutral current (FCNC) processes (like b→s, b→d) are fobidden at the tree level in the Standard Model.
Proceed only at low rate via higher-order loop diagrams.
Ideal place to search for new physics.



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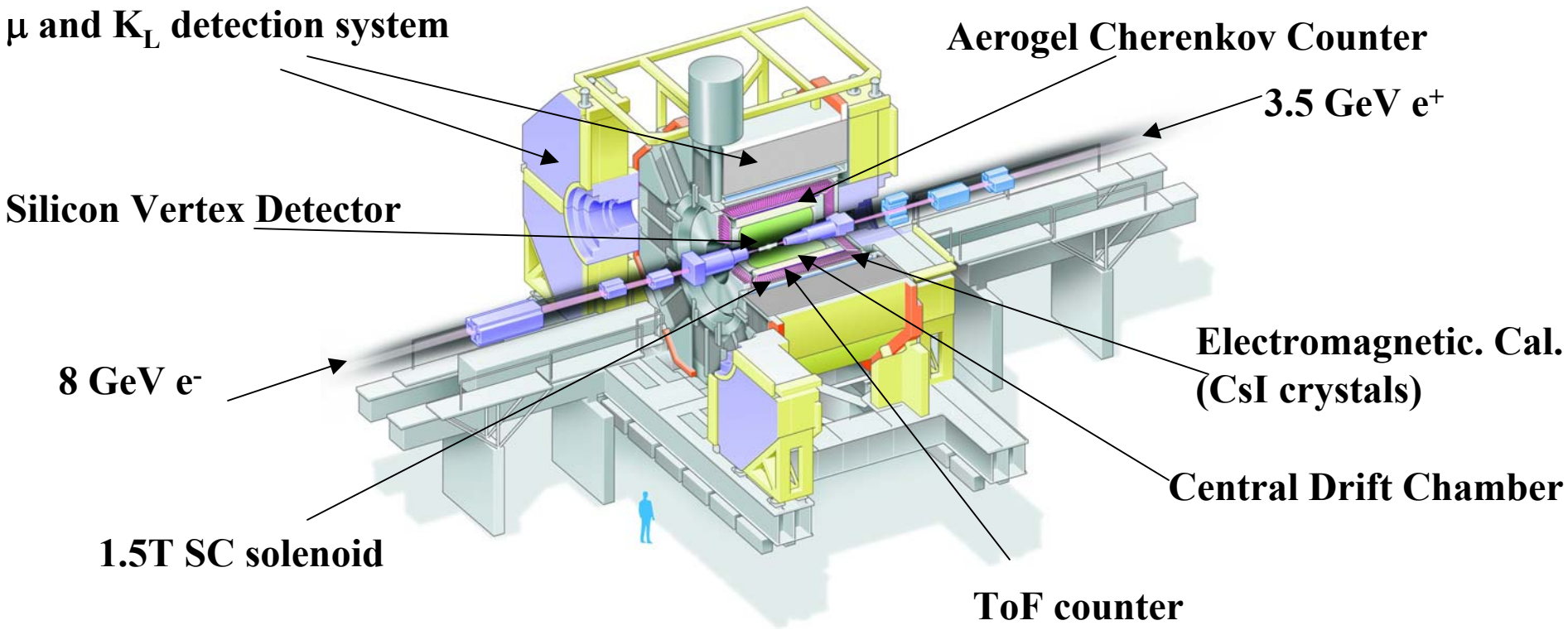
Belle spectrometer at KEK-B



Accumulated luminosity: 258 fb^{-1}. This talk: most analyses on the 140 fb^{-1} data set ≅ 152 M BB-pairs

b → sγ inclusive

b → sγ rate: sensitive to deviations from the SM, world average in good agreement with SM predictions.

Photon energy E_γ distribution: depends on m_b and Fermi motion parameter in the B system (parameters of HQE); also important for the determination of V_{ub} in semileptonic B decays.

Previous measurement by CLEO: $E_\gamma > 2.0$ GeV.

Belle: extend the energy range to $E_\gamma > 1.8$ GeV to cover >95% of the rate.

b → sγ inclusive

Fully inclusive measurement:
detect photons

Problem: huge backgrounds

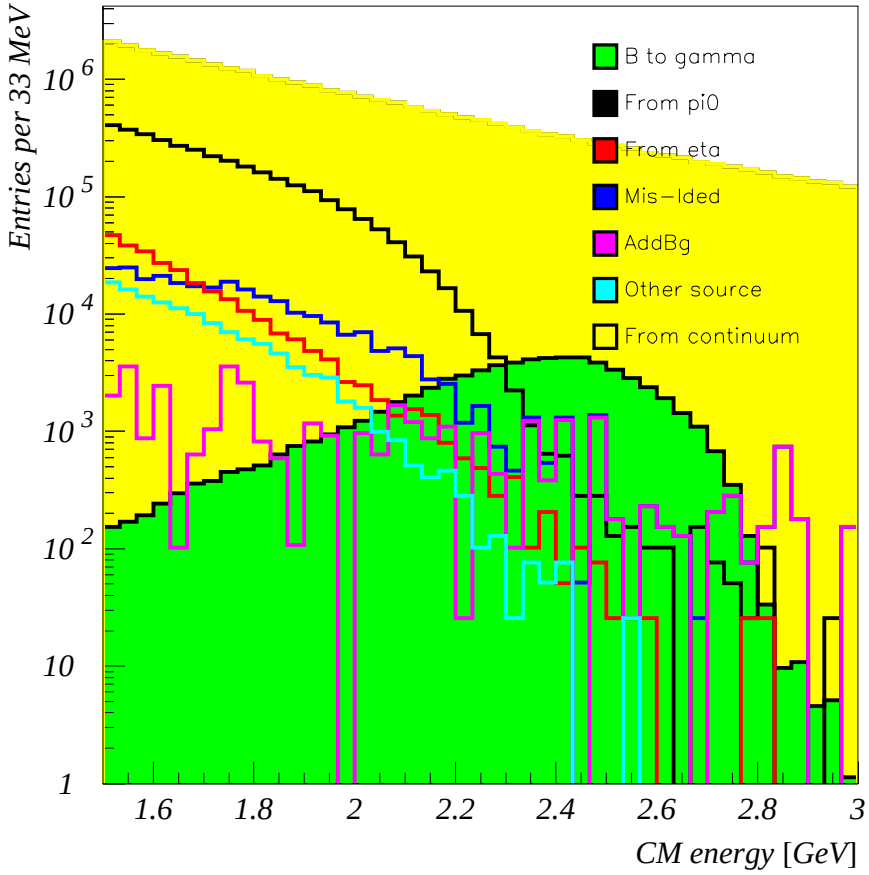
continuum ee →qq events

π^0, $\eta \rightarrow \gamma\gamma$ from B decays

misidentified photons

γ from beam background

Additional challenge: extend the E_γ region to lower values



b → sγ inclusive

- Consider all photons with $E_\gamma > 1.5$ GeV
- Reject candidates compatible with π^0, $\eta \rightarrow \gamma\gamma$
- Apply stringent continuum cuts (event shape and energy flow variables)
- Subtract the remaining continuum component as determined with off-resonance data
- Other sources: inferred from data-corrected MC and subtracted

- Signal selection optimisation: maximize the significance in the $1.8\text{GeV} < E_\gamma < 1.9$ GeV interval

data sample 140/fb

b → sγ inclusive

Results

Branching ratio:

$$BR(b\to s\gamma)=(3.55\pm0.32^{+0.30+0.11}_{-0.31\ -0.07})\cdot10^{-4}$$

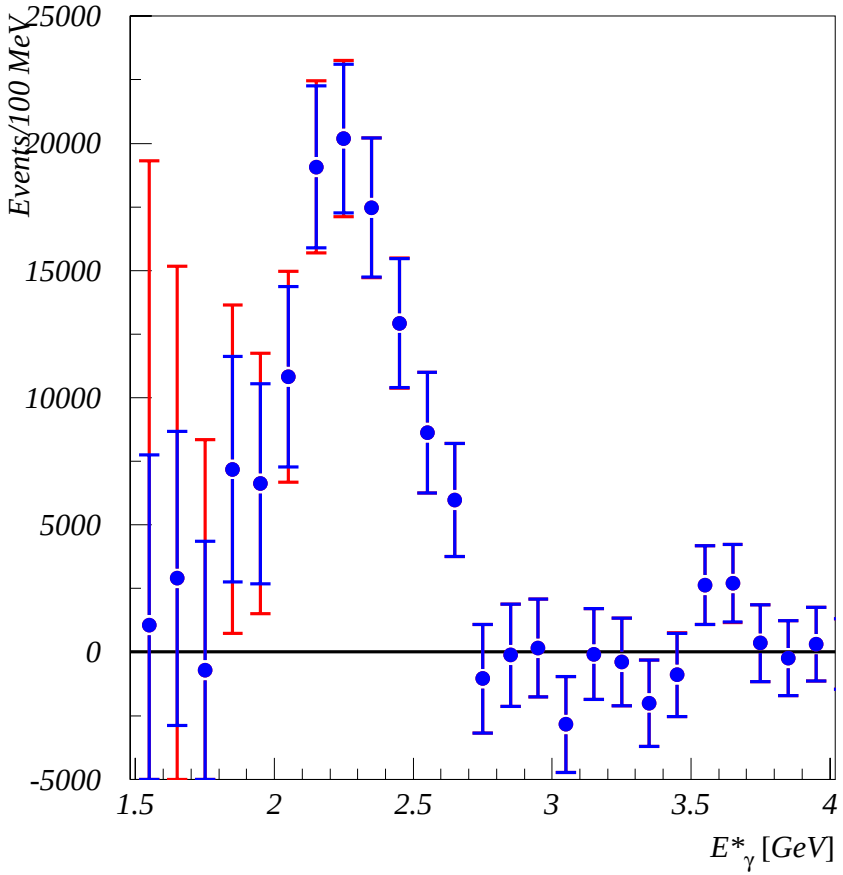
Photon energy E_γ distribution:

first moment:

$$\langle E_\gamma\rangle = (2.292 \pm 0.026\pm0.034)\ \text{GeV}$$

second moment: $\langle E_\gamma^2\rangle - \langle E_\gamma\rangle^2 =$

$$(0.0305 \pm 0.0074\pm0.0063)\ (\text{GeV})^2$$



published: hep-ex/0403004v2

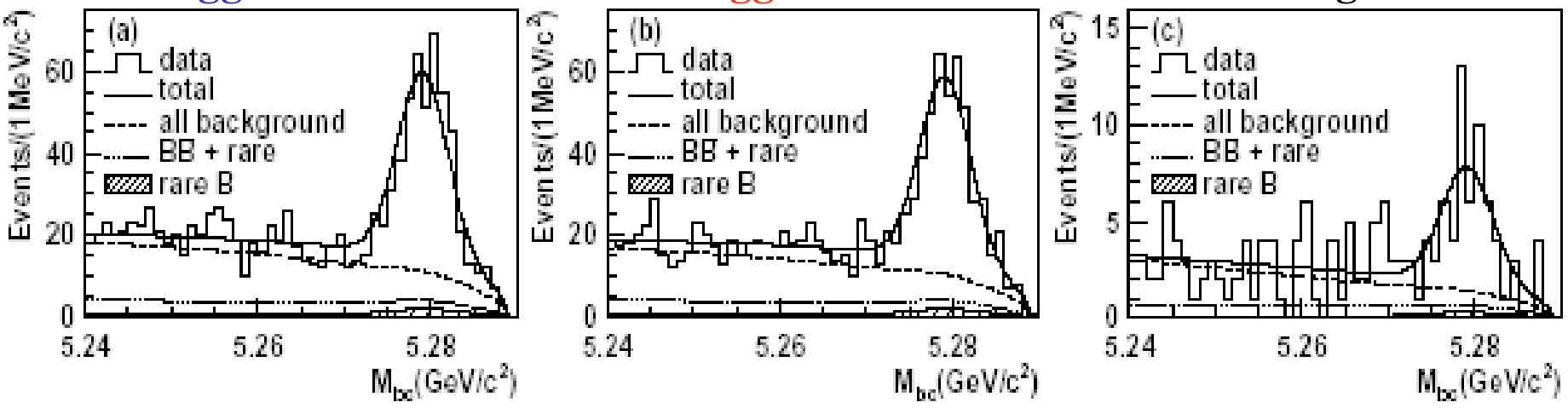
CP asymmetry in B → $X_s \gamma$

Inclusive measurement: pseudo-reconstruction of B→$X_s\gamma$.

For X_s use K^{+-} or K_S with 1-4 π (0 or 1 π^0), $K^{+-}K^{+-}K^{+-}(\pi^{+-})$, $K_SK^{+-}K^{+-}(\pi^{+-})$.

data sample 140/fb

tagged as b **tagged as bbar** **ambiguous**



Signal extraction: kinematic variable $M_{bc} = \sqrt{(E^{*2}_{beam} - |p^*_B|^2)}$

CP asymmetry in $B \to X_s \gamma$

BELLE

CP asymmetry

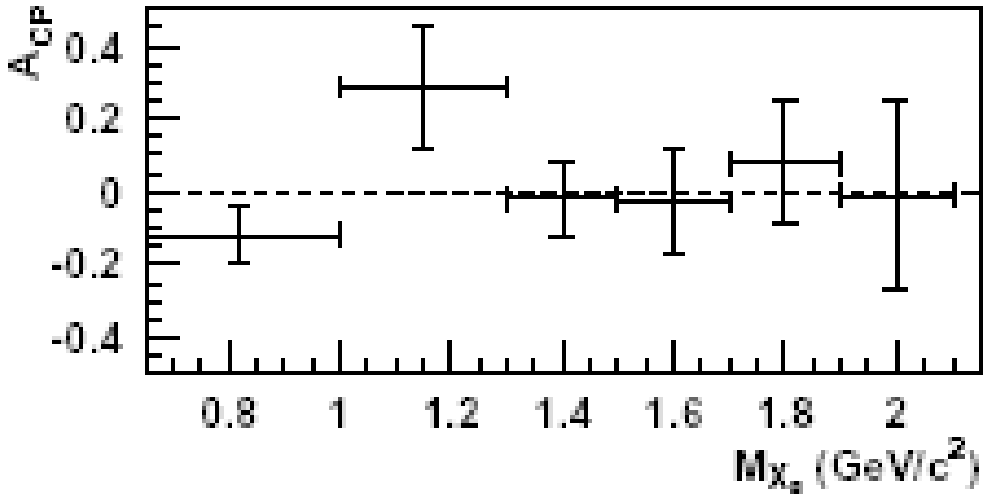
$A_{CP} = (\Gamma(b \to s\gamma)-\Gamma(\bar{b} \to \bar{s}\gamma))/(\Gamma(b \to s\gamma)+\Gamma(\bar{b} \to \bar{s}\gamma))$

SM expectation +0.5%

For events with X_s<2.1 GeV/c^2

$A_{CP} = -0.002 \pm 0.050(stat) \pm 0.030(syst)$

published: hep-ex/0308038



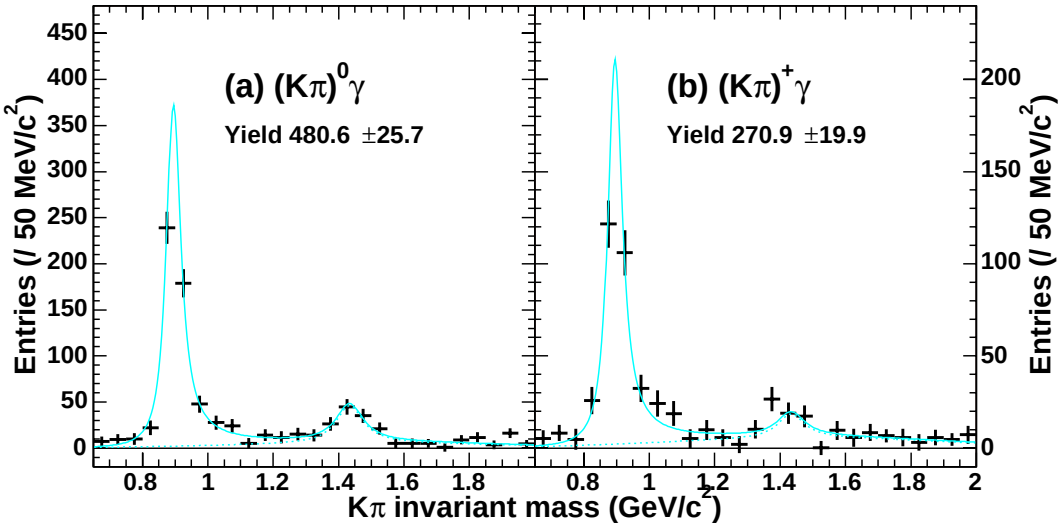
A_{CP} vs. X_s

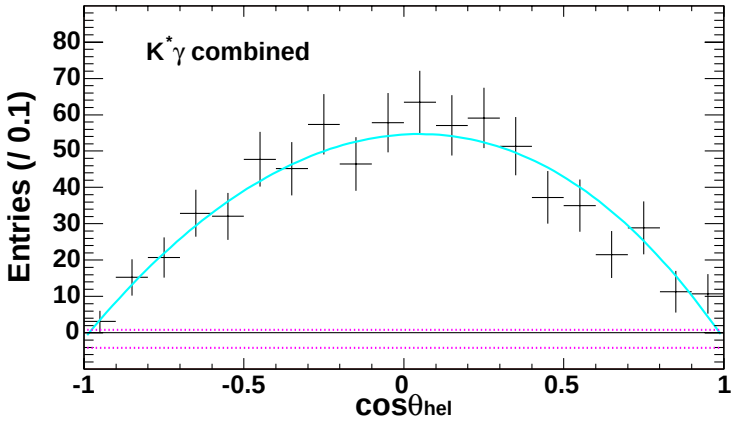
$B \to K^*\gamma$

- **Photon candidates with π^0/η veto**
- **K*(892) reconstructed in 4 final states:**

$K^+\pi^-$, $K^0_s\pi^0$, $K^+\pi^0$, $K^0_s\pi^+$ with $|M(K\pi) - M(K^*)_r| < 75$ MeV/c^2

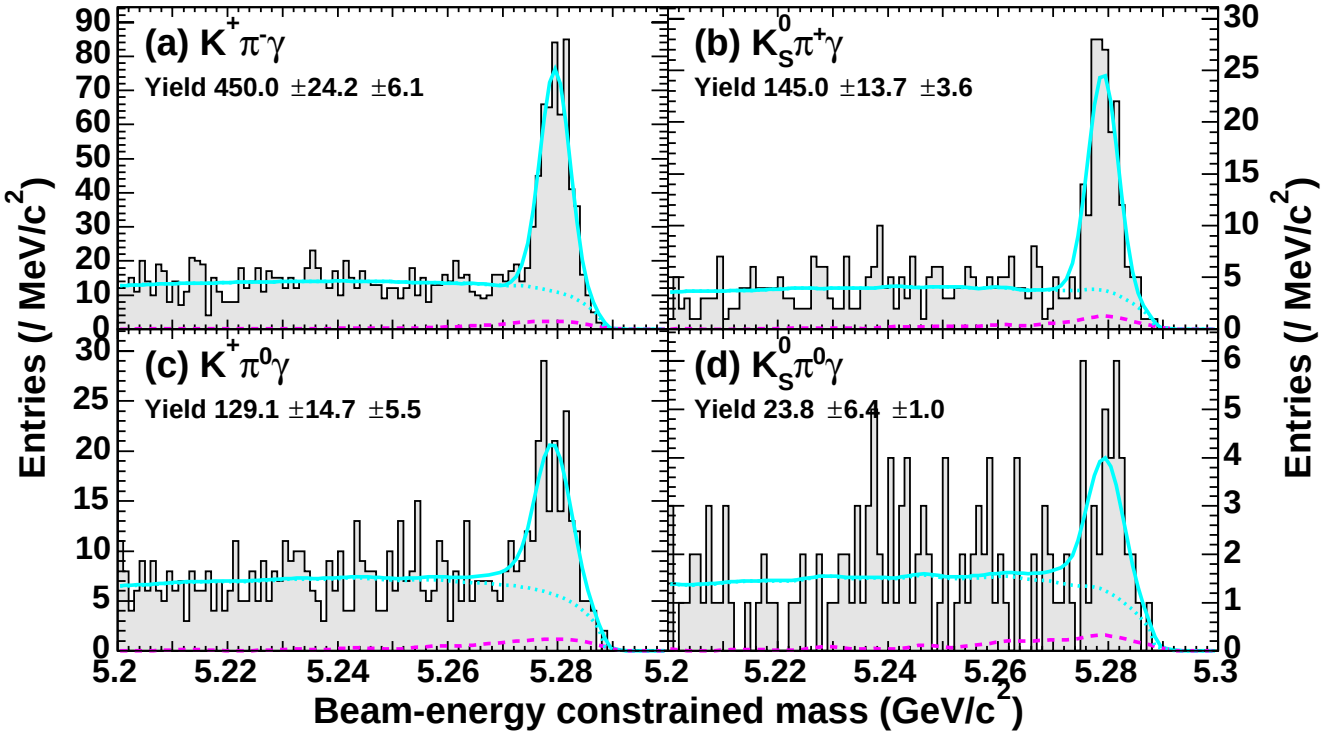
- **BKG suppression against $e^+e^- \to qq(\gamma)$ by event shape var.**





data sample 78/fb

$B \to K^*\gamma$ braching fractions



$$M_{bc} = \sqrt{(E^{*2}_{beam} - |p^*_B|^2)}$$

$$BR(B^0 \to K^{*0}\gamma) = (4.01 \pm 0.21 \pm 0.17) \cdot 10^{-5} \quad SM \approx (6.9 \pm 2.1) \cdot 10^{-5}$$

$$BR(B^+ \to K^{*+}\gamma) = (4.25 \pm 0.31 \pm 0.24) \cdot 10^{-5} \quad SM \approx (7.4 \pm 2.3) \cdot 10^{-5}$$

$B \to K^*\gamma$ asymmetries

Isospin asymmetry Δ_{0+} =

$$\frac{(\tau_{B^+}/\tau_{B^0})\,BR(B^0 \to K^{*0}\gamma) - BR(B^+ \to K^{*+}\gamma)}{(\tau_{B^+}/\tau_{B^0})\,BR(B^0 \to K^{*0}\gamma) + BR(B^+ \to K^{*+}\gamma)}$$

$\Delta_{0+} = +0.012 \pm 0.044(\text{stat}) \pm 0.026(\text{syst})$ **SM: 5-10%**

CP asymmetry

SM<<0.01

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

$$\frac{1}{(1-2w)} \quad \frac{N(\bar{B} \to \bar{K}^*\gamma) - N(B \to K^*\gamma)}{N(\bar{B} \to \bar{K}^*\gamma) + N(B \to K^*\gamma)}$$

(w= dilution due to imperfect tagging)

$A_{CP} = -0.015 \pm 0.044(\text{stat}) \pm 0.012(\text{syst})$

published: hep-ex/0402042

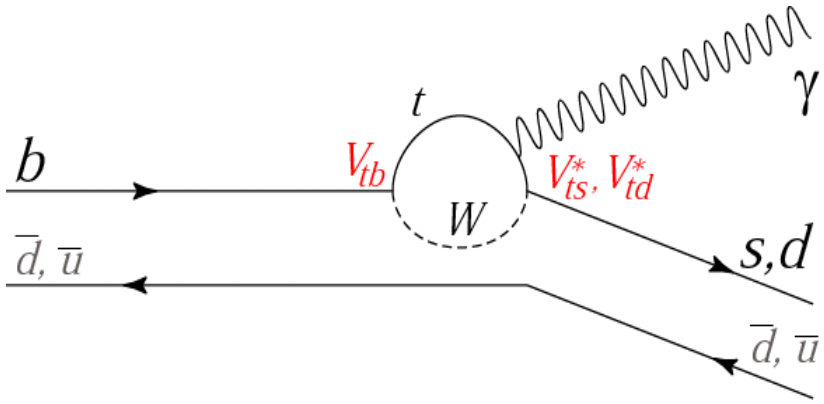
b → dγ exclusive: B → ργ, ωγ

Supressed by $(V_{td}/V_{ts})^2$ vs b → sγ

SM prediction for $B^+ \rightarrow \rho^+\gamma$

BR around 1×10^{-6}

Not yet observed.



Potentially interesting:

Measurement of V_{td}/V_{ts}

CP violation could be sizeable in SM (order 10%)

$B \to \rho\gamma, \omega\gamma$

Exclusive $B \to \rho^0/\rho^+/\omega\gamma$ ($\rho^0 \to \pi^+\pi^-$, $\rho^+ \to \pi^0\pi^+$, $\omega \to \pi^+\pi^-\pi^0$)

measurements on a data sample of 140/fb

BG : $B \to K^*\gamma$ missid., $B \to \rho/\omega\pi^0$, continuum

Continuum rejection: by Fisher event shape variable, vertexing, flavor-tag

Signal yield: Use 2-D unbinned maximum likelihood fit in two variables $M_{bc} = \sqrt{(E^{*2}_{beam} - |p^*_B|^2)}$ and $\Delta E = E^*_B - E^*_{beam}$

Simultaneous fit to 3 signals + 2 $K^*\gamma$ assuming isospin relations:

$$Br(B^+ \to \rho^+\gamma) = 2(\tau(B^+)/\tau(B^0))Br(B^0 \to \rho^0\gamma) = 2(\tau(B^+)/\tau(B^0))Br(B^0 \to \omega\gamma)$$

B → ργ, ωγ

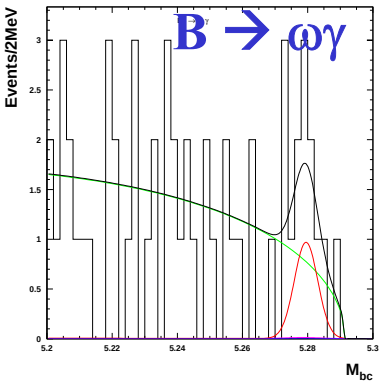
Fit result:

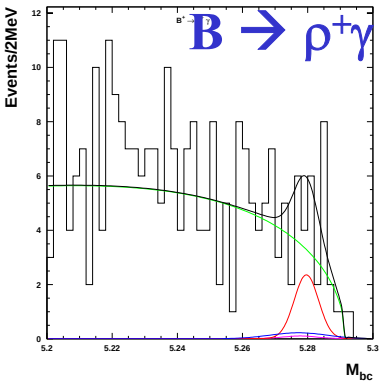
-signal

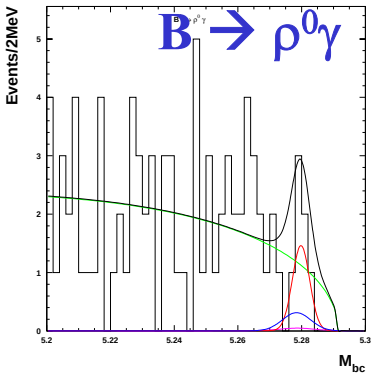
-K*γ

-qq

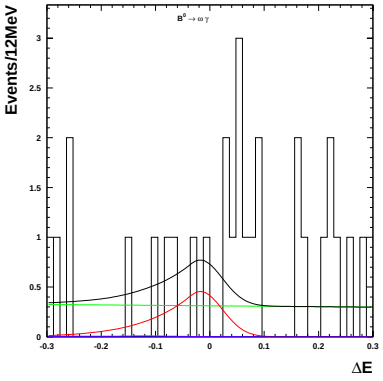
-ρ/ωπ^0

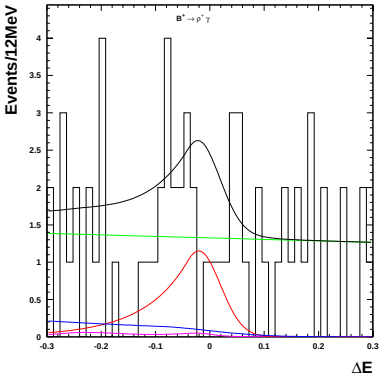


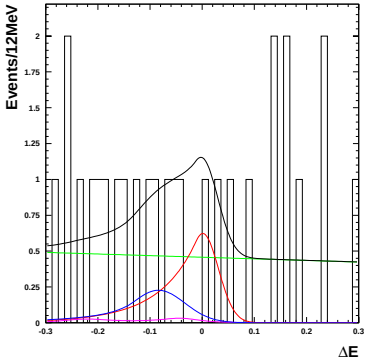




$$M_{bc} = \sqrt{(E^{*2}_{beam} - |p^*_B|^2)}$$







$$\Delta E = E^*_B - E^*_{beam}$$

$B \to \rho\gamma, \omega\gamma$

$B \to \rho/\omega\gamma$ 27.4 net signal (from the simultaneous fit)

significance 3.5 (including the systematic error)

$BF(B \to \rho^+\gamma) = (1.8\ ^{+0.6}_{-0.5} \pm 0.1)\ 10^{-6}$ **preliminary!**

$(= 2(\tau(B^+)/\tau(B^0))Br(B^0 \to \rho^0\gamma) = 2(\tau(B^+)/\tau(B^0))Br(B^0 \to \omega\gamma)$)

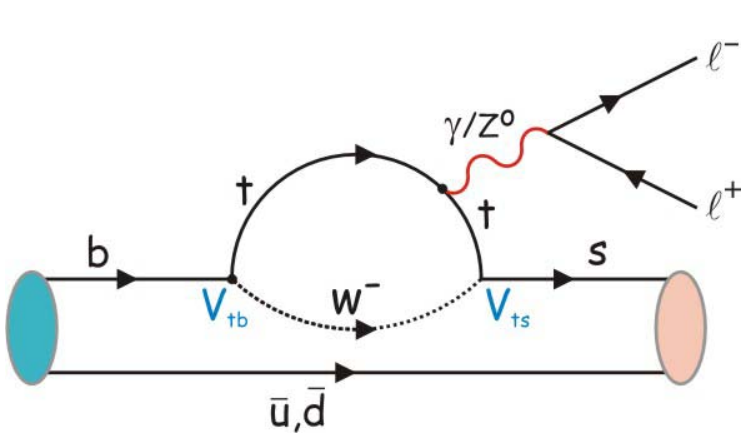
First evidence for the $b \to d\gamma$ process

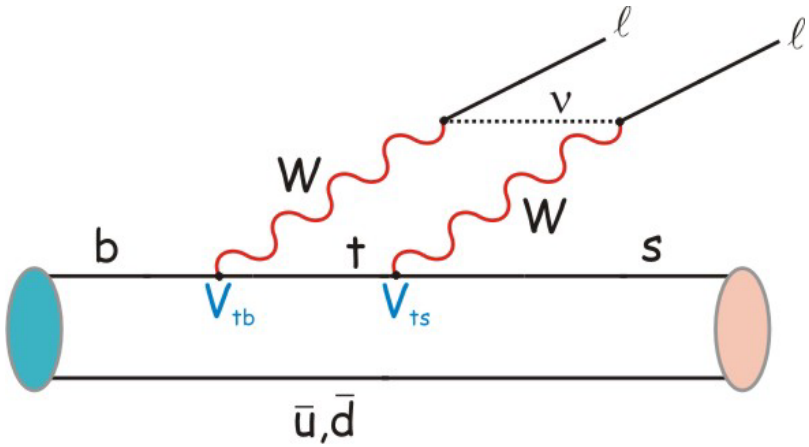
In agreement with SM

SM predictions ($B^+ \to \rho^+\gamma$): $(0.90 \pm 0.34) \times 10^{-6}$ Ali, Parkhomenko

$(1.58 +0.53 -0.46) \times 10^{-6}$ Bosch, Buchalla

$B \rightarrow K^* l^+ l^-$





$b \rightarrow s\, l^+l^-$ was first measured in $B \rightarrow K\, l^+l^-$ by Belle.

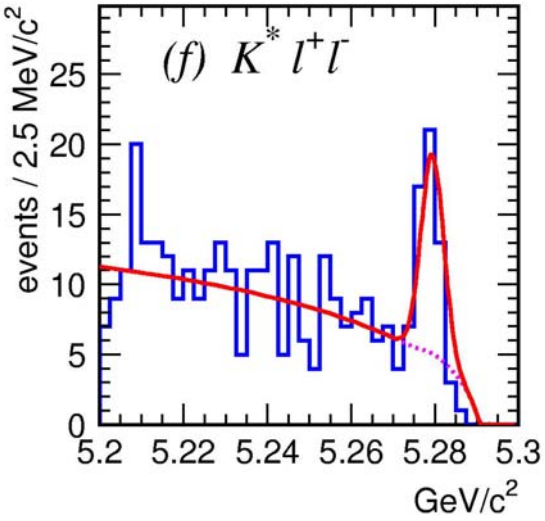
With 140/fb of data, search for $K^*\, l^+l^-$ and update $K\, l^+l^-$.

Important for further searches for the physics beyond SM:

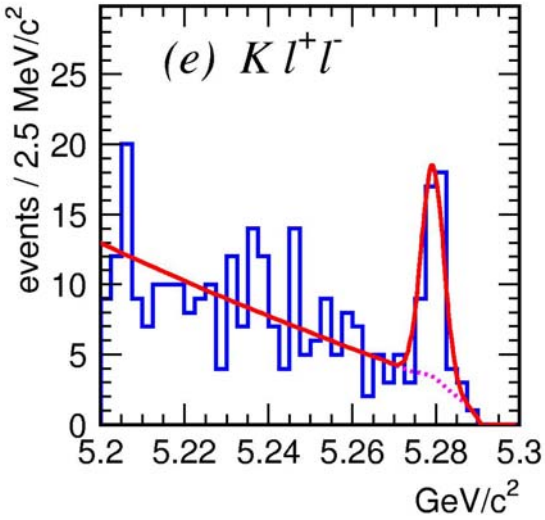
backward-forward asymmetry A_{FB} in $K^*\, l^+l^-$

$B \to K^* l^+ l^-$

- K^*: $K^+\pi^-$, $K^0_s\pi^+$, $K^+\pi^0$ with $|M(K\pi)-M(K^*)|<75$ MeV/c^2
- K: charged or neutral
- Lepton pair: e or μ, p(e)>0.4 GeV/c, p(μ)>0.7 GeV/c
  veto on J/Ψ, Ψ(2S)



first observation

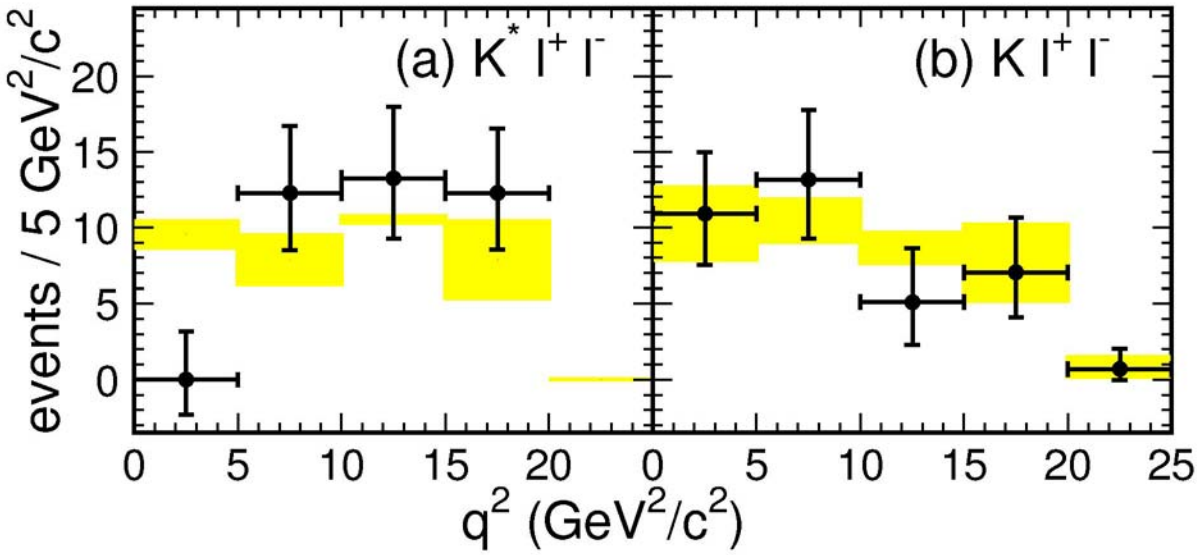


$$M_{bc} = \sqrt{(E^{*2}_{beam} - |p^*_B|^2)}$$

$B \to K^* l^+ l^-$

Results based on 140 fb^{-1}

- **BR($B \to K^* l^+ l^-$) = $(11.5^{+2.6}_{-2.4} \pm 0.8 \pm 0.2)\ 10^{-7}$ observation**
- **BR($B \to K\, l^+ l^-$) = $(4.8^{+1.0}_{-0.9} \pm 0.3 \pm 0.1)\ 10^{-7}$ update with more data**



$q^2 = M_{ll}^2\, c^2$

yellow: SM expect.

published: PRL 91, 261601 (2003)

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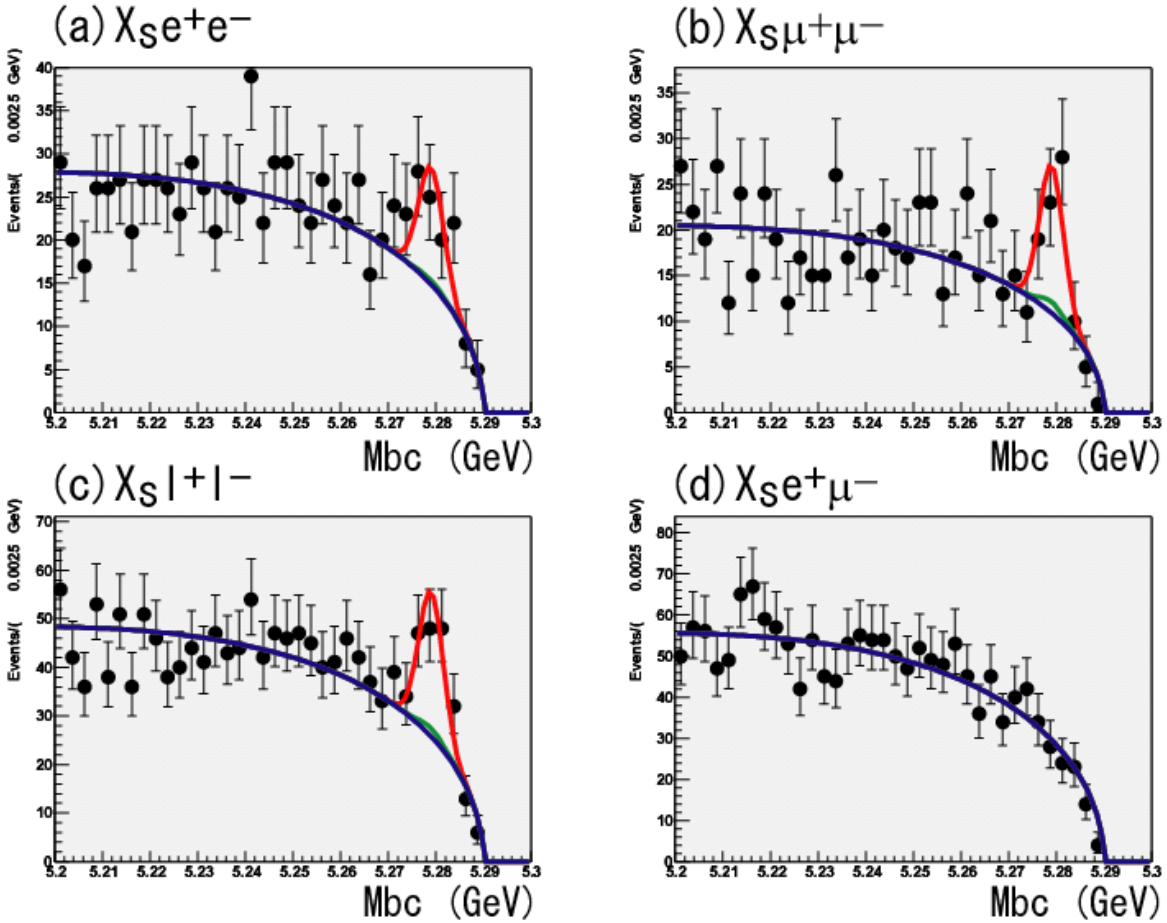
$B \to X_s l^+ l^-$ update

Inclusive b → s l^+l^- measurement is a model independent probe for new physics; first measured by Belle in 2002.

Inclusive measurement: pseudo-reconstruction of $B \to X_s l^+l^-$.



For X_s use K^{+-} or K_S with 0-4π (0 or 1 π^0).

Background from $B \to X_s J/\psi$, $X_s \psi(2S)$ removed by M_{ll} veto, contamination from $B \to X_s \pi^+\pi^-$ is subtracted

data sample 140/fb

$B \to X_s l^+ l^-$ update

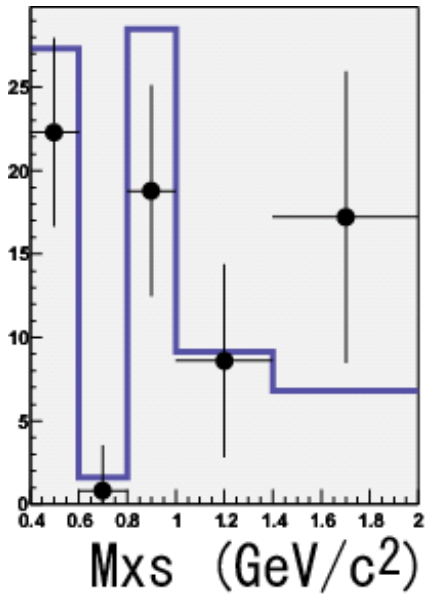
$BR(B \to X_s e^+ e^-) = (4.45 \pm 1.32^{+0.84}_{-0.79}) \times 10^{-6}$

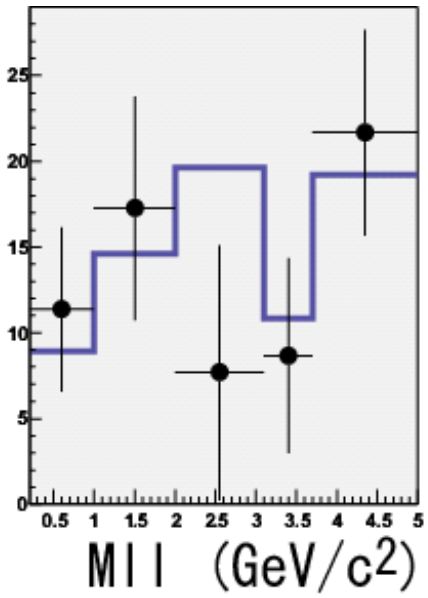
$BR(B \to X_s \mu^+ \mu^-) = (4.31 \pm 1.06^{+0.74}_{-0.70}) \times 10^{-6}$

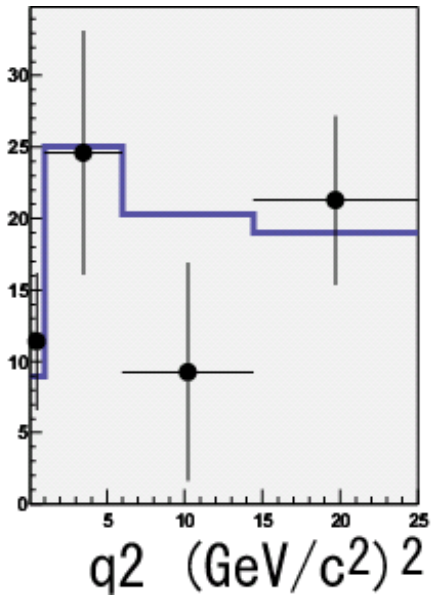
$BR(B \to X_s l^+ l^-) = (4.39 \pm 0.84^{+0.78}_{-0.73}) \times 10^{-6}$

preliminary!

SM: $(4.2 \pm 0.7) \times 10^{-6}$







Summary

- New measurement of the $b \to s\gamma$ inclusive rate and moments with an extended energy range, $E_\gamma > 1.8$ GeV
- First evidence for a $b \to d\gamma$ transition, $B \to \rho/\omega\gamma$, and a new mode in $B \to X_s l^+ l^-$, $B \to K^* l^+ l^-$ (first observation)
- BR and asymmetries in $b \to s\gamma$ and $b \to s l^+ l^-$ transitions are in good agreement with SM, but some interesting results are statistically limited
- We are entering an exciting phase of precision measurements (e.g. A_{FB}, q^2 dependence in $K^{(*)}ll$)
- By this summer the data sample will be doubled

Back-up slides

b → sγ inclusive

$$BR(b\to s\gamma)=(3.55\pm0.32^{+0.30+0.11}_{-0.31\ -0.07})\cdot10^{-4}$$

$$<E_\gamma>=(2.292\pm0.026\pm0.034)\ \text{GeV}$$

$$<E_\gamma^2>-<E_\gamma>^2=(0.0305\pm0.0074\pm0.0063)\ (\text{GeV})^2$$

Sources of systematic errors:

Rate: data/MC efficiency ratio (0.208 10^{-4}), N_{BB} (+0.139 –0.160), photon detection efficiency (0.072), photons from B decays (0.054), choice of fitting functions (0.048), on-off data subtraction (0.026),...

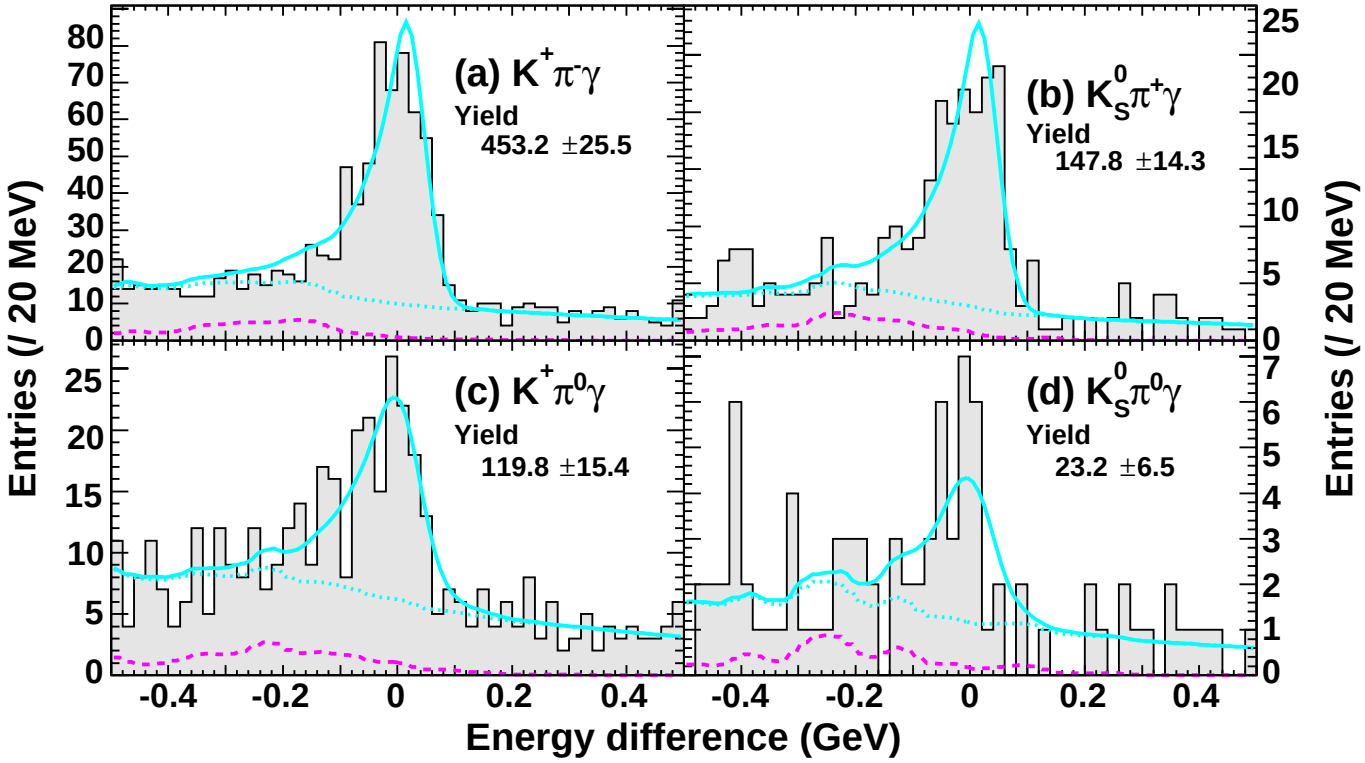
First moment: energy resolution function (1%), data/MC efficiency ratio (0.9%)

Second moment : data/MC efficiency ratio (17%)

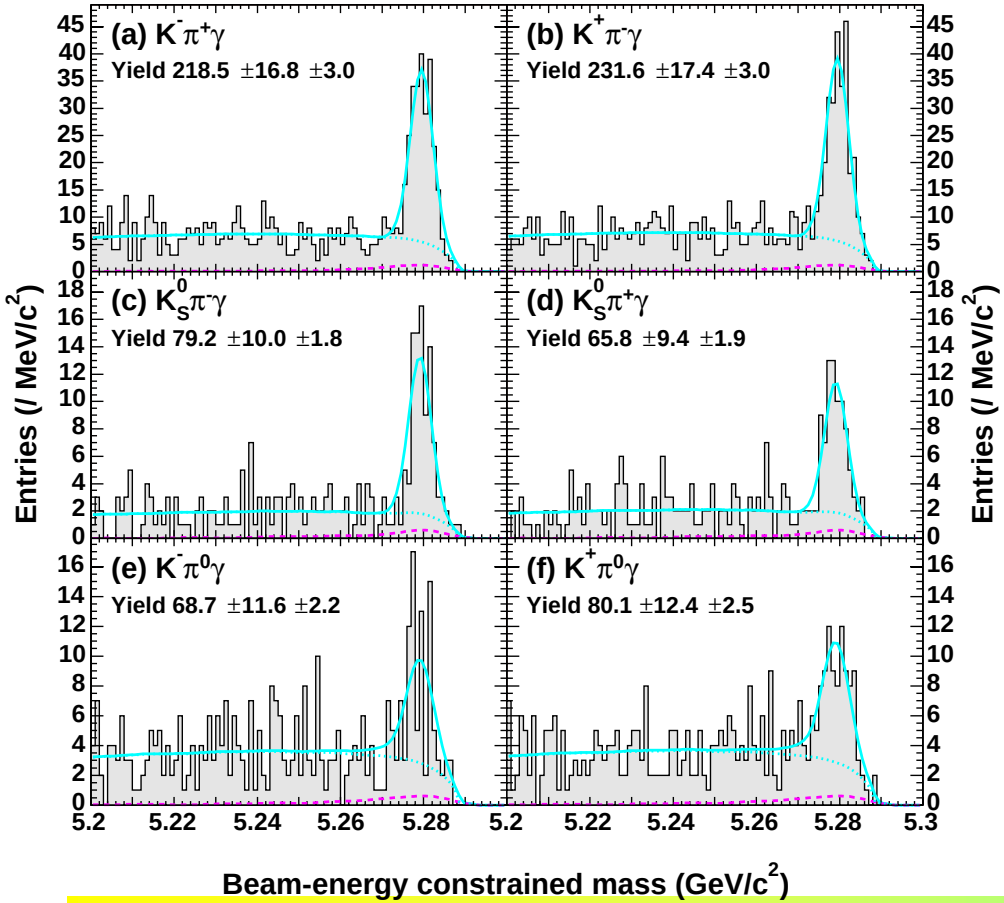
Published: hep-ex/0403004v2.
Changes vs. v1: improved treatment of the $B\to X_sJ/\psi$, $J/\psi\to\gamma$ Y background.

$B \to K^*\gamma$

$$\Delta E = E^*_B - E^*_{beam}$$



$B \to K^*\gamma$ CP asymmetry



$$A_{CP}(B \to K^*\gamma) =$$

$$-0.015 \pm 0.044(\text{stat}) \pm 0.012(\text{syst})$$

SM expectation <0.01

$B \to \rho\gamma, \omega\gamma$

Simultaneous fit

Signal yield: Use 2-D unbinned maximum likelihood fit in two variables $M_{bc} = \sqrt{(E^{*2}_{beam} - |p^*_B|^2)}$ and $\Delta E = E^*_B - E^*_{beam}$

Simultaneous fit to 3 signals + 2 $K^*\gamma$

Fit region: $M_{bc} > 5.2$GeV, $|\Delta E| < 0.3$ GeV

	$B \to \rho^0\gamma$	$B \to \rho^+\gamma$	$B \to \omega\gamma$
Events in the fit	280	749	197
Signal yield	6.3	15.2	5.9

significance 3.5 (including the systematic error)

$B \to \rho\gamma, \omega\gamma$

Fit result, individual channels:

Unbinned maximum likelihood fit in two variables

$M_{bc} = \sqrt{(E^{*2}_{beam} - |p^*_B|^2)}$ and $\Delta E = E^*_B - E^*_{beam}$

Fit region: $M_{bc} > 5.2$GeV, $|\Delta E| < 0.3$ GeV

	$B \to \rho^0\gamma$	$B \to \rho^+\gamma$	$B \to \omega\gamma$
Events in the fit	280	749	197
Signal yield	$3.6^{+3.6+0.7}_{-2.8\ -0.9}$	$15.5^{+7.1}_{-6.3} \pm 1.5$	$8.8\ ^{+4.8}_{-4.0} \pm 1.2$
Significance	1.2σ	2.5σ	2.3σ