$b \to s \ell^+ \ell^-$ at Belle

~ Exclusive and Inclusive Analysis Results

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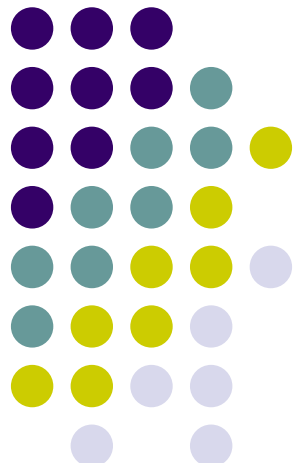
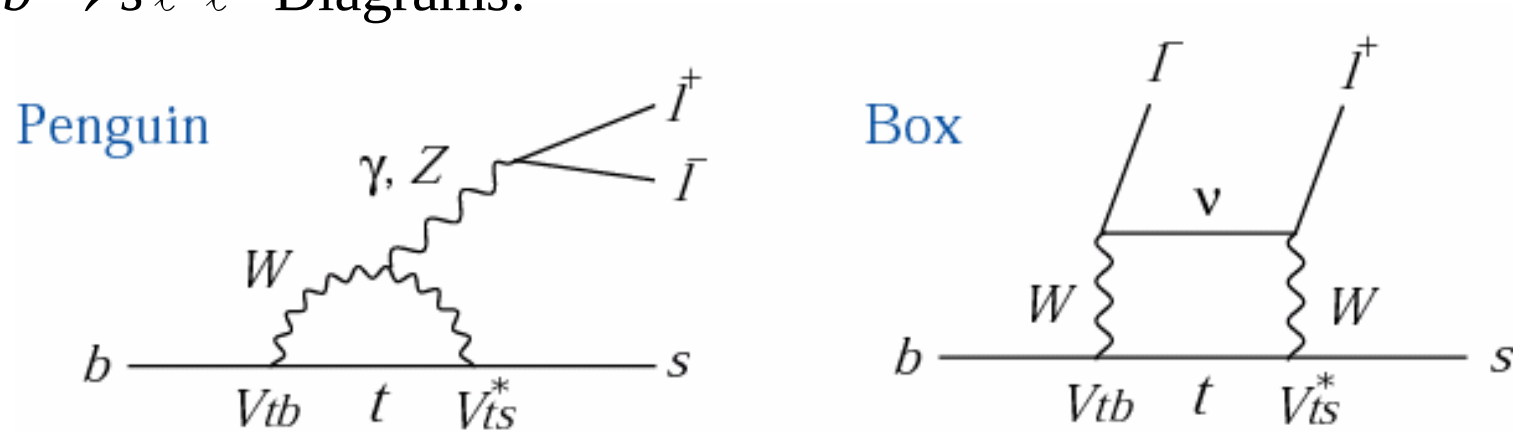
Flavor Physics and CP Violation



Introduction

$b \to s \ell^+ \ell^-$ Diagrams:



Flavor Changing Neutral Current (FCNC) process is sensitive to new physics (SUSY, charged Higgs…).

Very rare decays(BF~10^{-6}(exclusive),10^{-5}(inclusive)).

Exclusive mode – experimentally easy to analyze.

Inclusive mode – theoretically easy to extract parameters.

Effective Hamiltonian Approach

$$\frac{d\Gamma\left(b\to s\ell^+\ell^-\right)}{d\hat{s}}=\left(\frac{\alpha}{4\pi}\right)^2\frac{G_F^2 m_b^5\left|V_{ts}^*V_{tb}\right|^2}{48\pi^3}\left(1-\hat{s}\right)^2$$

$$\times\left[\left(1+2\hat{s}\right)\left(\left|C_9^{\text{eff}}\right|^2+\left|C_{10}^{\text{eff}}\right|^2\right)+\left(1+\frac{\hat{s}}{2}\right)\left|C_7^{\text{eff}}\right|^2+12\,\text{Re}\left(C_7^{\text{eff}}C_9^{\text{eff}}\right)\right]$$

$$\left(\hat{s}=M^2(\ell^+\ell^-)/M_B^2\right)$$

$C_7^{\text{eff}}, C_9^{\text{eff}}, C_{10}^{\text{eff}}$ is C_7, C_9, C_{10} + higher order correction

Standard Model $C_7^{\text{eff}}, C_9^{\text{eff}}, C_{10}^{\text{eff}}$ are calculated to NNLO

Ali-Lunghi-Greub-Hiller, hep-ph/0112300

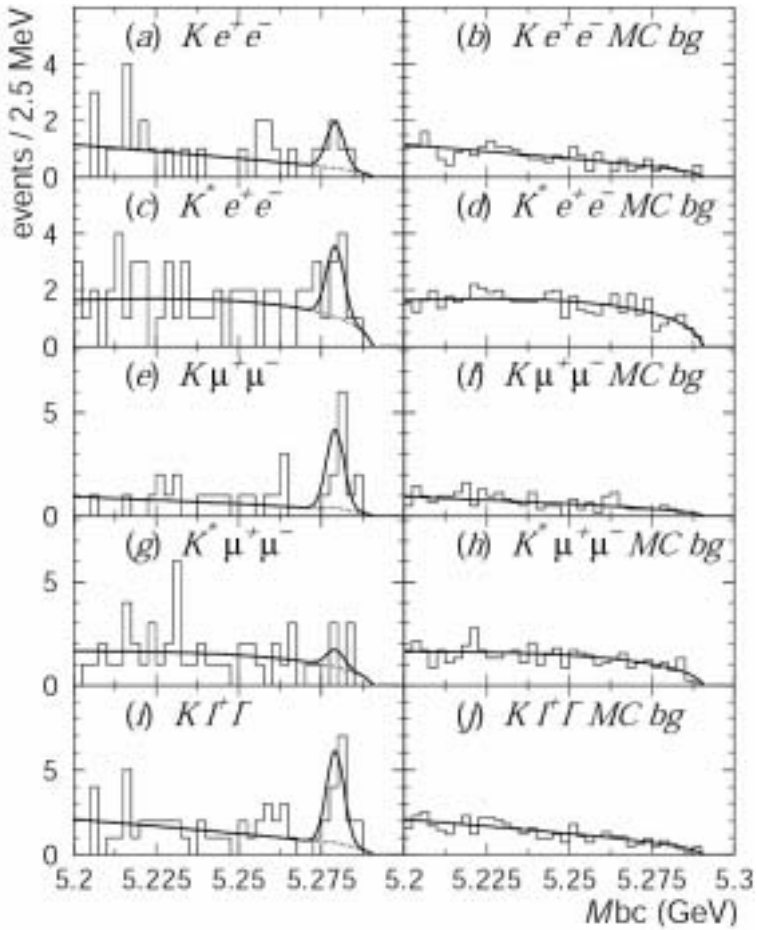
Predicted Branching Fraction

Mode	BF($\times 10^{-6}$)	Mode	BF($\times 10^{-6}$)
$X_s e^+e^-$	6.89 ± 1.01	$K^* e^+e^-$	1.58 ± 0.49
$X_s \mu^+\mu^-$	4.15 ± 0.70	$K^* \mu^+\mu^-$	1.19 ± 0.39
		$K\ell^+\ell^-$	0.35 ± 0.12

Beyond SM …is expressed as corrections to SM

Exclusive mode analysis results

29fb^{-1} data



mode	#signal	BF($\times 10^{-6}$)	signif.
Ke^+e^-	$4.1^{+2.7+0.6}_{-2.1-0.8}$	<1.3	2.5
$K^*e^+e^-$	$6.3^{+3.7+1.0}_{-3.0-1.1}$	<5.6	2.5
$K\mu^+\mu^-$	$9.5^{+3.8+0.8}_{-3.1-1.0}$	$0.99^{+0.40+0.13}_{-0.32-0.14}$	4.7
$K^*\mu^+\mu^-$	$2.1^{+2.9+0.9}_{-2.1-1.0}$	<3.1	–
$K\ell^+\ell^-$	$13.6^{+2.9+0.9}_{-2.1-1.0}$	$0.75^{+0.40}_{-0.32}\pm 0.09$	5.3

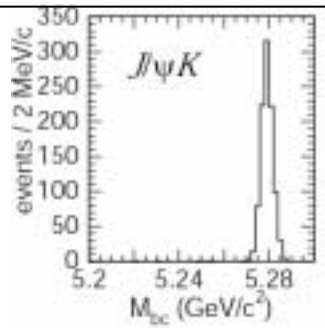
$B \to K\ell^+\ell^-$ Observation.

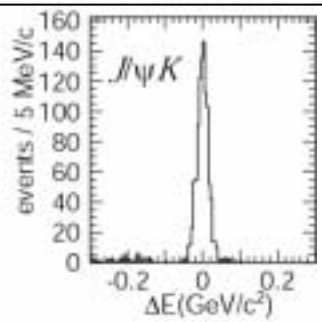
PRL88 021801(2002)

A.Ishikawa, Ph.D Thesis, Nagoya Univ. (2002)

Inclusive Analysis in General

Two kinematical variables to identify B mesons





Signals are identified by fitting Beam energy constraint mass (M_{bc}) through this talk.

Beam constraint mass

$$M_{bc} = \sqrt{E_{beam}^2 - p_B^2}$$

Energy difference

$$\Delta E = E_B - E_{beam}$$

qq continuum/charmonium background suppression

Thrust angle, B flight direction, Energy difference (ΔE), veto mass region

Double b->clv->slv, c->slv decay background suppression

Lepton ID, Fisher Discriminant (Missing Mass, Total Energy)

$B \to X_s \ell^+ \ell^-$ Inclusive mode analysis

Signal Requirement

$X_s = (K^+ \text{ or } K_S) + (0 \sim 4)\pi$ (upto one π^0)

Yield from M_{bc} fit(Gaussian and ARGUS function)

Best candidate based on ΔE, vertex quality, B flight direction and K - $\ell^\pm$ angular correlation

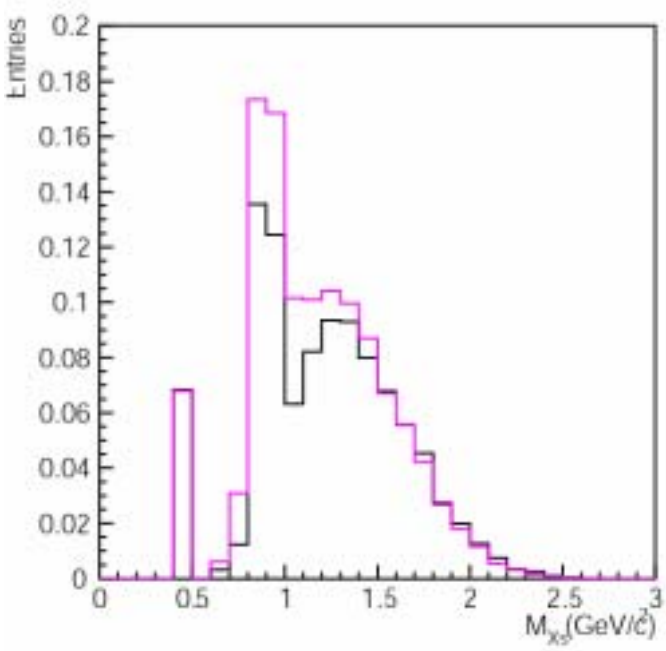
Reconstruction efficiency:

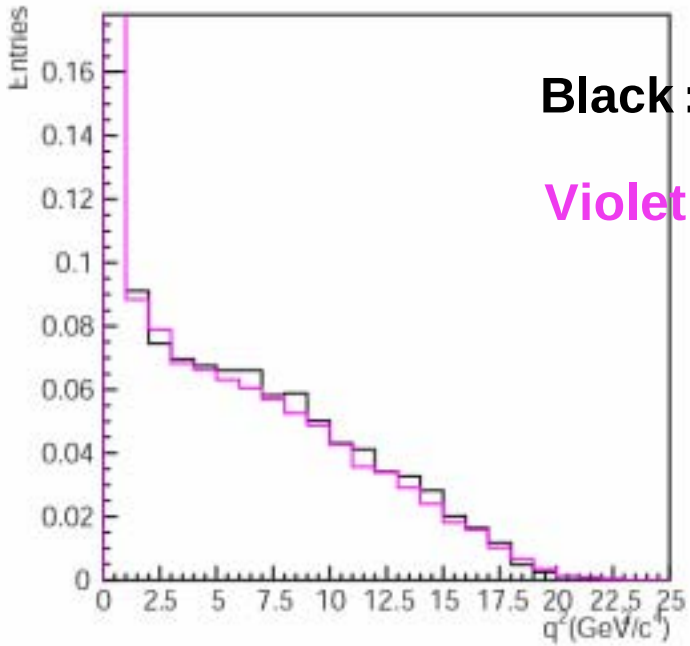
Inclusive: ~4%

Exclusive: ~10%

43fb-1 data used in this inclusive analysis.

$B \to X_s \ell^+ \ell^-$ MC decay Modeling





Black : $B \to X_s \mu^+ \mu^-$

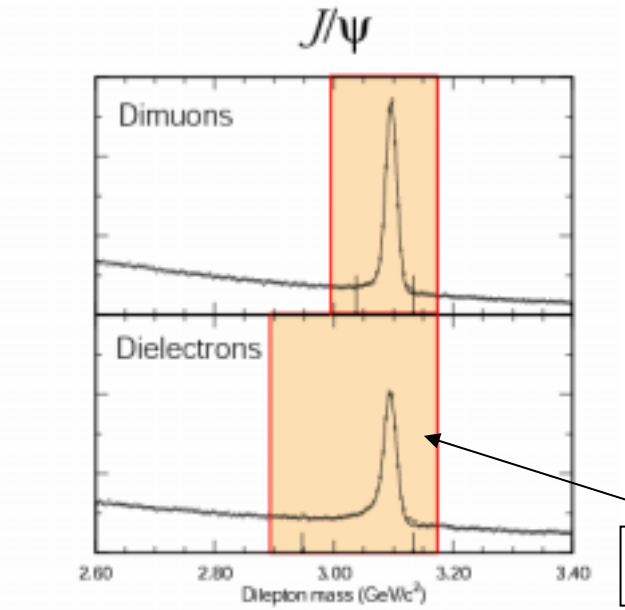
Violet : $B \to X_s e^+ e^-$

Based on the NNLO calculation.

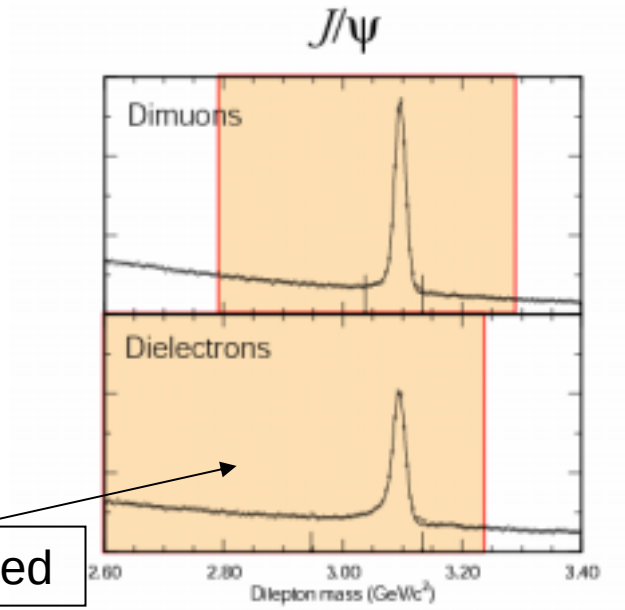
[Ali-Lunghi-Greub-Hiller, hep-ph/0112300]

J/ψ Suppression

For exclusive modes



For inclusive modes



Rejected

Tight charmonia veto:

$$-0.35\text{GeV}/c^2 < M(\mu\mu) - M(J/\psi) < 0.2\text{GeV}/c^2$$

$$-0.30\text{GeV}/c^2 < M(\mu\mu) - M(\psi') < 0.15\text{GeV}/c^2$$

$$-0.60\text{GeV}/c^2 < M(ee) - M(J/\psi) < 0.15\text{GeV}/c^2$$

$$-0.30\text{GeV}/c^2 < M(ee) - M(\psi') < 0.15\text{GeV}/c^2$$

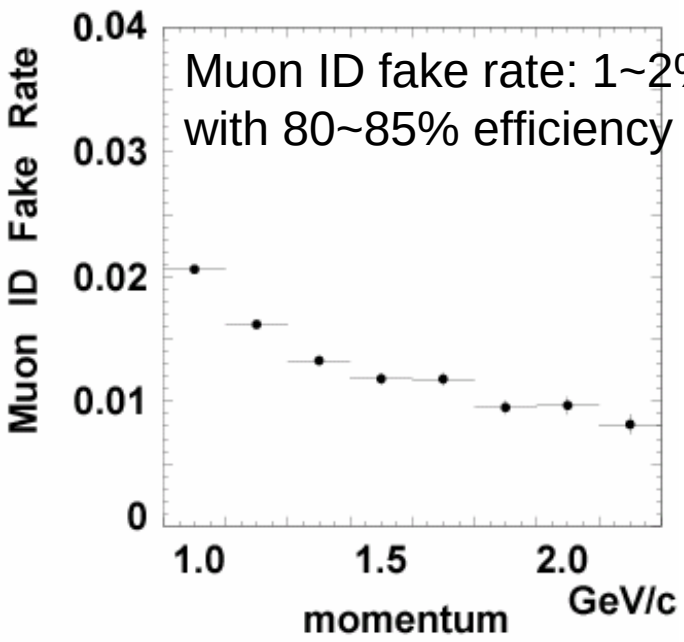
Charmonium contaminations after veto:

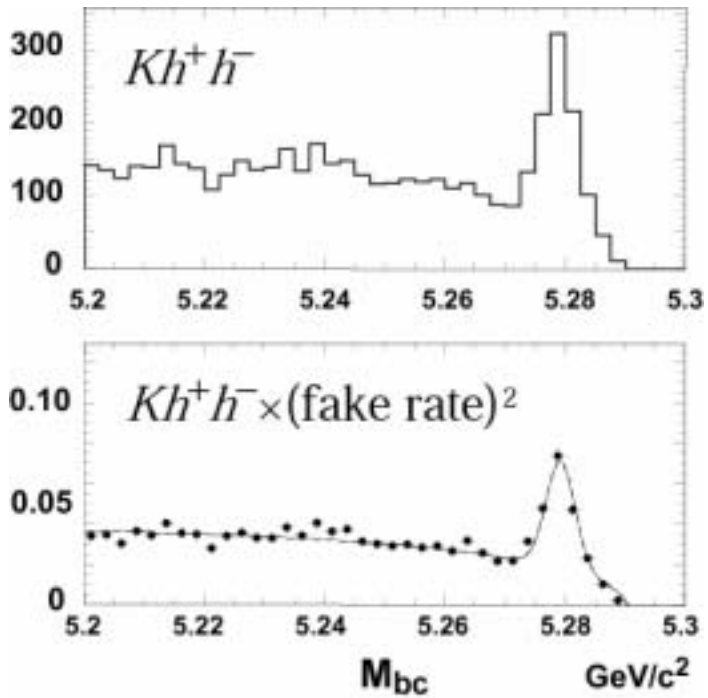
0.5 ± 0.3 events for $X_s e^+ e^-$

0.3 ± 0.1 events for $X_s \mu^+ \mu^-$

$B \to X_s h^+ h^-$ Background

Doubly misidentified h^+h^- as $\mu^+\mu^-$





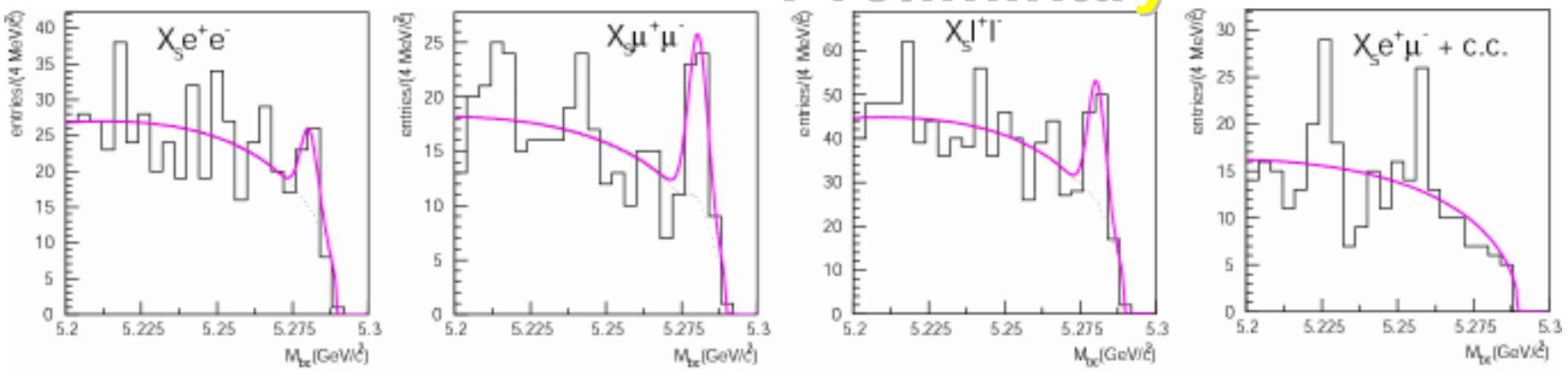
Background Estimation:

$N(B \to X_s h^+ h^-)$ x mis-ID(fake) rate measured w/ data

$2.4^{+0.5}_{-0.4}$ Xsh^+h^- background events @ $43\, fb^{-1}$

Inclusive mode analysis results

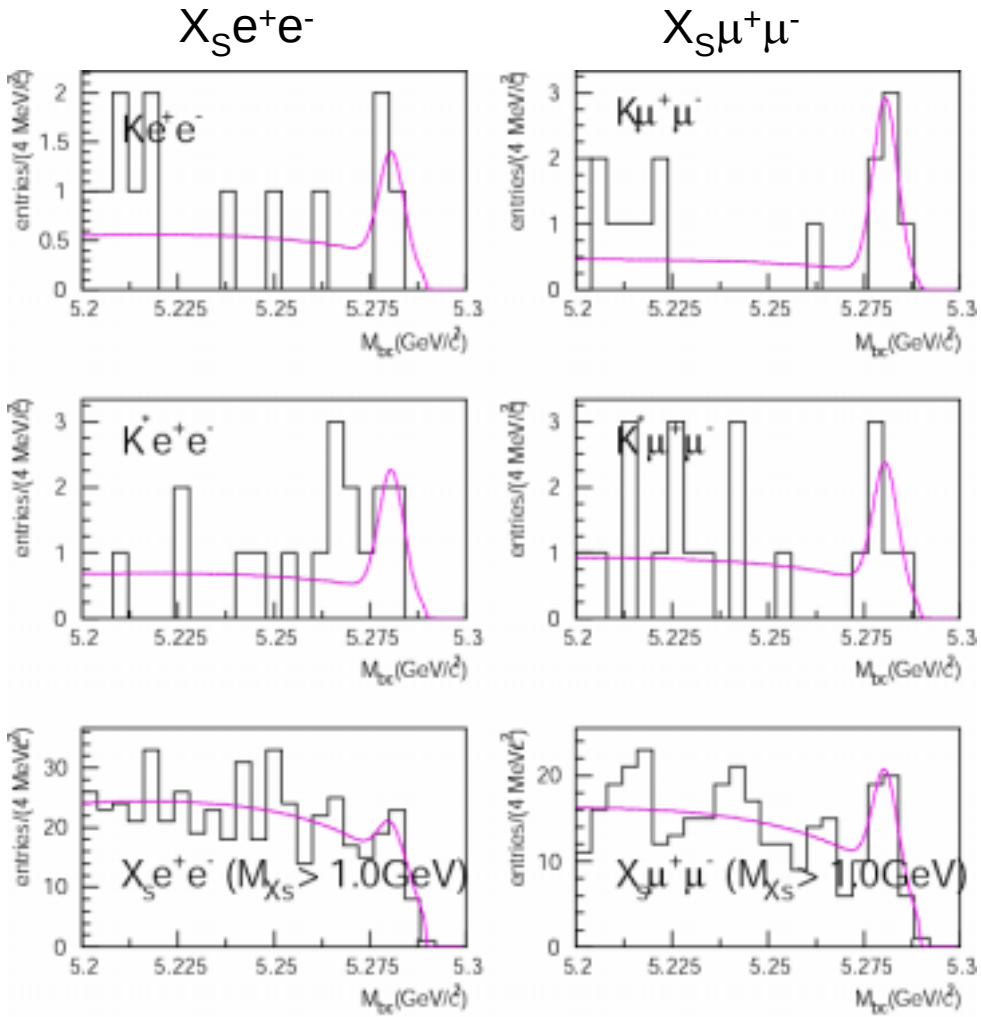
Preliminary



Mode	#Signal	BF($\times 10^{-6}$)	UL($\times 10^{-6}$)	Signif.	
$X_s e^+ e^-$	$16.6^{+8.0+3.9}_{-7.3-3.8}$	$(5.1^{+2.6+1.3}_{-2.4-1.2})$	<11.0	2.1	
$X_s \mu^+ \mu^-$	$30.7^{+7.9+5.4}_{-7.4-3.8}$	$8.9^{+2.3+1.6}_{-2.1-1.7}$	–	4.4	First Evidence!
$X_s \ell^+ \ell^-$	$47.6^{+11.0+9.6}_{-10.4-8.0}$	$7.1^{+1.6+1.4}_{-1.6-1.2}$	–	4.8	First Evidence!

Preliminary

M(Xs) slices of M_{bc} Distribution



K mass region

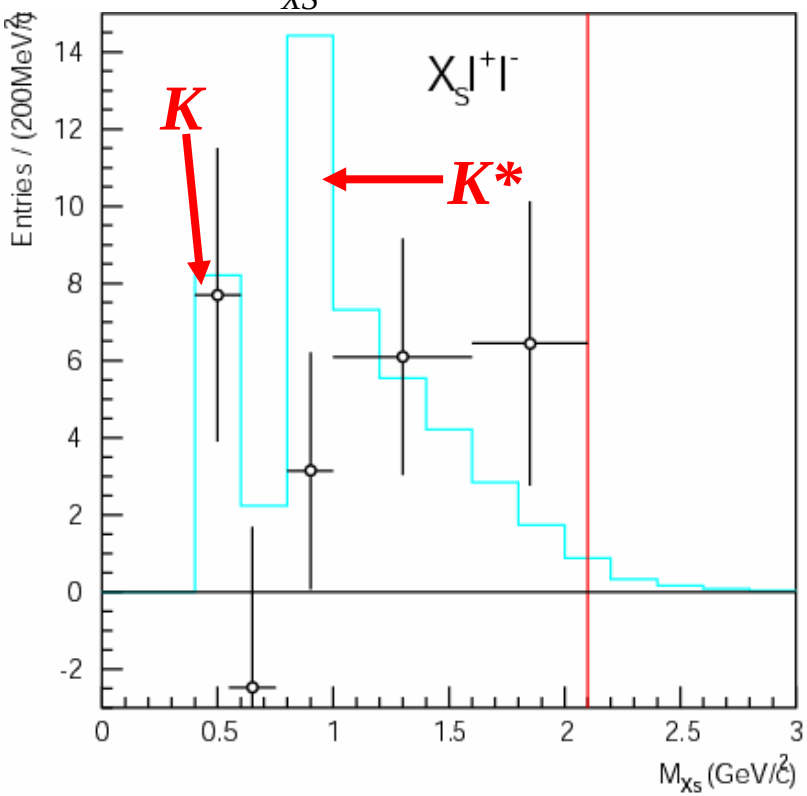
K* mass region

M(Xs)>1.0GeV/c^2 region

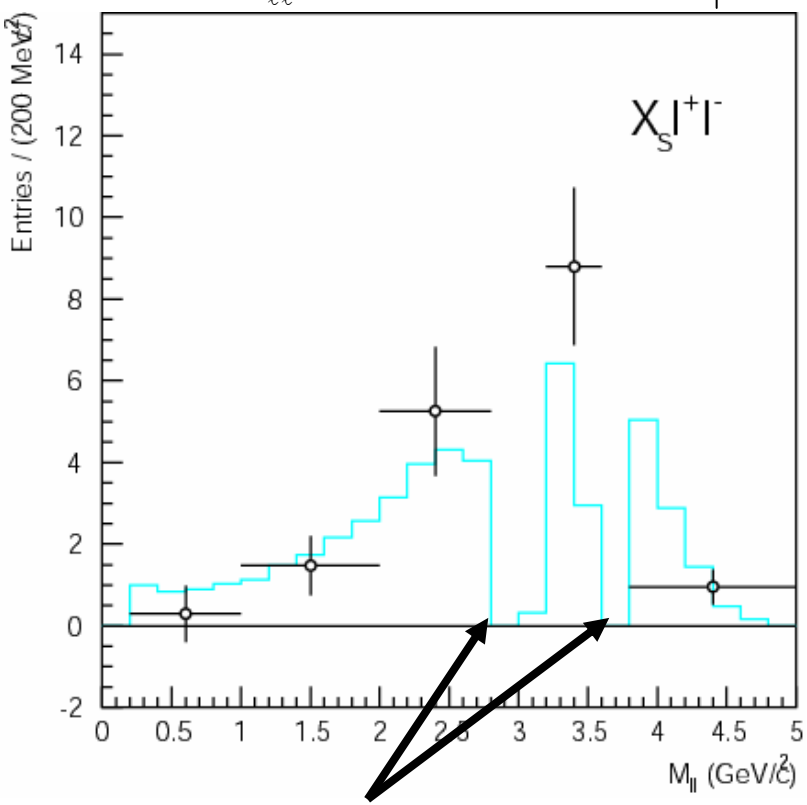
Inclusive mode analysis is consistent with the exclusive mode analysis in M(K), M(K*), and the higher mass region.

M_{X_S} and $M_{\ell\ell}$ Distribution

M_{XS} Distribution



$M_{\ell\ell}$ Distribution



J/psi and psi' vetoes

With higher statistics, more information will be obtained from M(Xs) and M(ll) distributions.

Systematic uncertainties

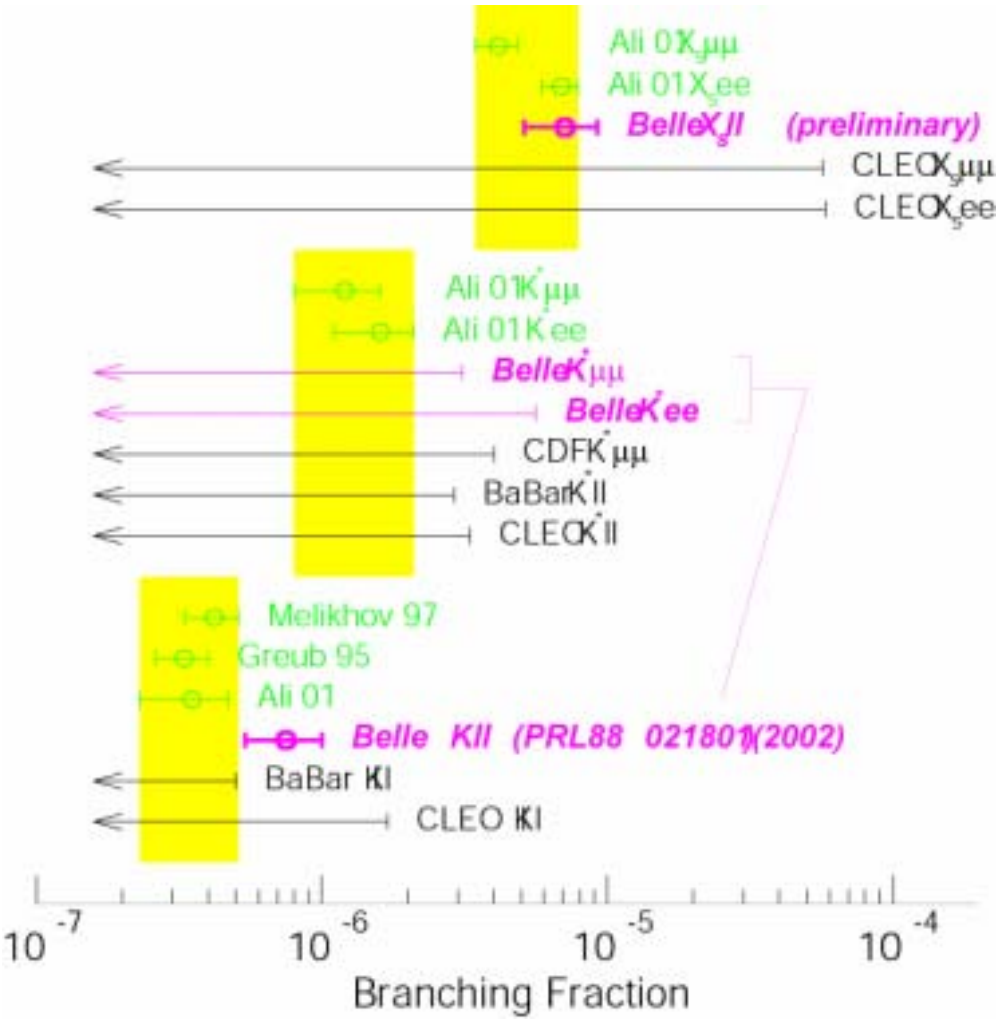
Source	$B \to X_s e^+ e^-$	$B \to X_s \mu^+ \mu^-$
Tracking	8.1%	8.0%
Kaon ID	1.9%	2.0%
Pion ID	0.8%	0.8%
Lepton ID	3.6%	4.4%
K_S detection	2.1%	1.5%
π^0 detection	2.0%	1.6%
MC Statistics	3.9%	4.1%
Decay modeling	$^{+14}_{-9}$%	$^{+16}_{-12}$%
Total	$^{+18}_{-14}$%	$^{+19}_{-16}$%

Exclusive & Inclusive: Summary

	Mode	Eff.	#Signal	BF($\times 10^{-6}$)	UL($\times 10^{-6}$)	Signif.	
Exclusive mode	Ke^+e^-	13.6%	$4.1^{+2.7+0.6}_{-2.1-0.8}$	–	<1.3	2.5	
	$K^*e^+e^-$	4.8%	$6.3^{+3.7+1.0}_{-3.0-1.1}$	–	<5.6	2.5	
	$K\mu^+\mu^-$	15.2%	$9.5^{+3.8+0.8}_{-3.1-1.0}$	$0.99^{+0.40+0.13}_{-0.32-0.14}$	–	4.7	
	$K^*\mu^+\mu^-$	5.9%	$2.1^{+2.9+0.9}_{-2.1-1.0}$	–	<3.1	–	
	$K\ell^+\ell^-$	–	$13.6^{+2.9+0.9}_{-2.1-1.0}$	$0.75^{+0.40}_{-0.32}\pm 0.09$	–	5.3	
Inclusive mode	$X_s e^+e^-$	3.6%	$16.6^{+8.0+3.9}_{-7.3-3.8}$	–	<11.0	2.1	
	$X_s\mu^+\mu^-$	3.8%	$30.7^{+7.9+5.4}_{-7.4-3.8}$	$8.9^{+2.3+1.6}_{-2.1-1.7}$	–	4.4	First Evidence!
	$X_s\ell^+\ell^-$	–	$47.6^{+11.0+9.6}_{-10.4-8.0}$	$7.1^{+1.6+1.4}_{-1.6-1.2}$	–	4.8	First Evidence!

Preliminary

Review of Measurements



Experimental results agree with SM theoretical predictions.

In several years experimental results will significantly improve the constraint on theoretical prediction well.

Conclusion

- Establish the existence of the decay $B \to K \ell^+ \ell^-$
- **First evidence on inclusive** $B \to X_s \ell^+ \ell^-$

Mode	#Signal	BF($\times 10^{-6}$)	UL($\times 10^{-6}$)	Signif.
$X_s e^+ e^-$	$16.6^{+8.0+3.9}_{-7.3-3.8}$	–	<11.0	2.1
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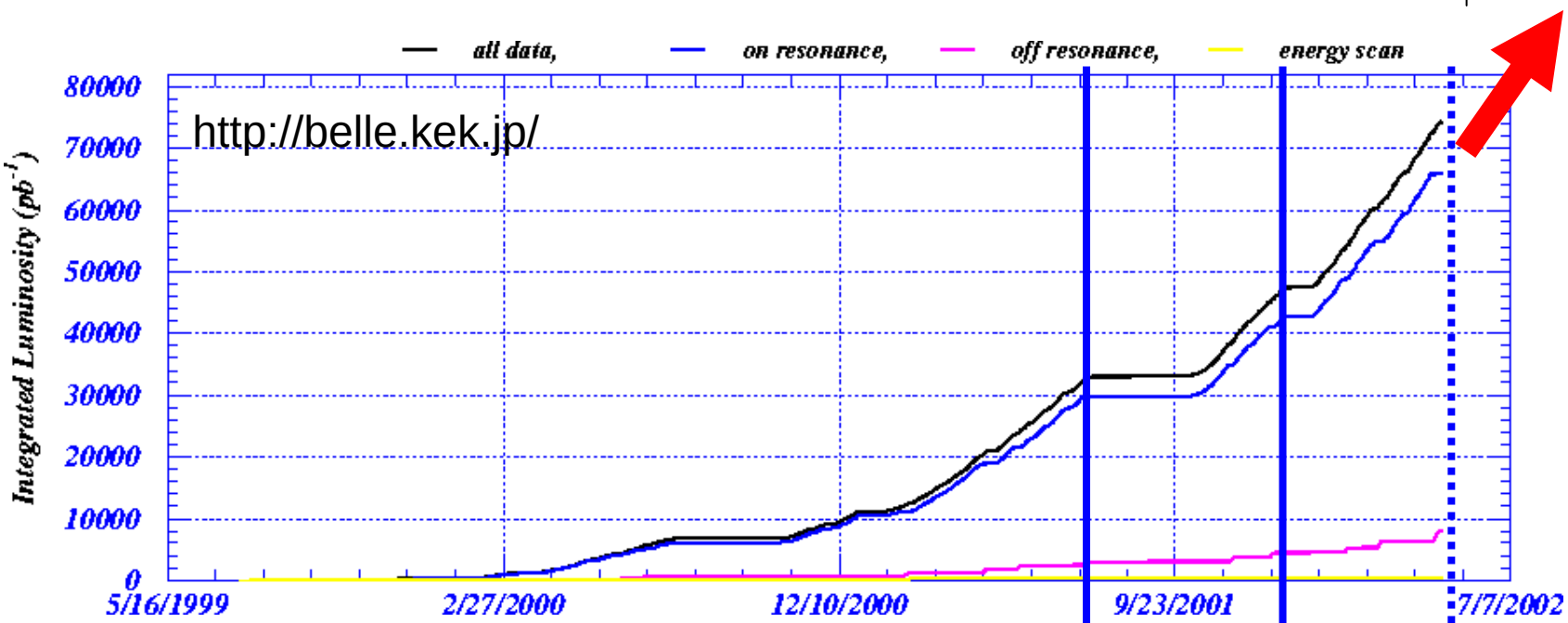
$X_s \ell^+ \ell^-$	$47.6^{+11.0+9.6}_{-10.4-8.0}$	$7.1^{+1.6+1.4}_{-1.6-1.2}$	–	4.8

- Both consistent with SM predictions
- Promising probe for Beyond SM physics at B-factories in next several years

…stay tuned and we will be back soon.

Belle/KEKB Data Accumulation



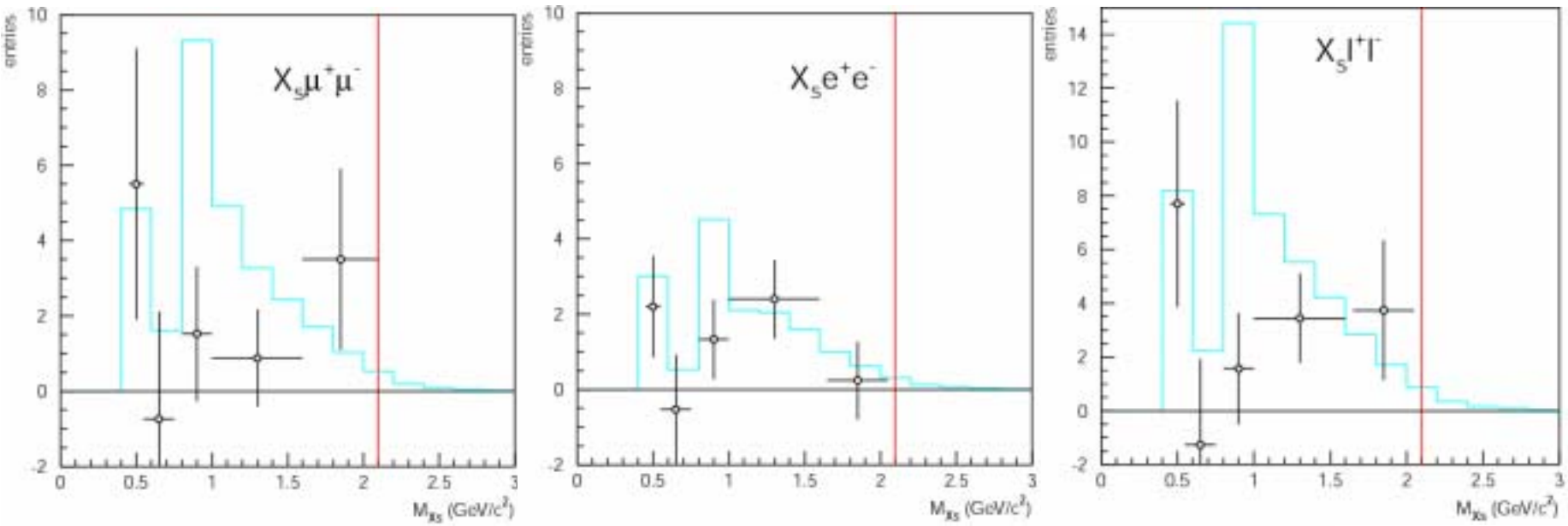
This talk presents…

$B \to K^{(*)}\ell\ell$ (Exclusive) $29.1\,fb^{-1}$

NEW $B \to X_s\ell\ell$ (Inclusive) $43\,fb^{-1}$

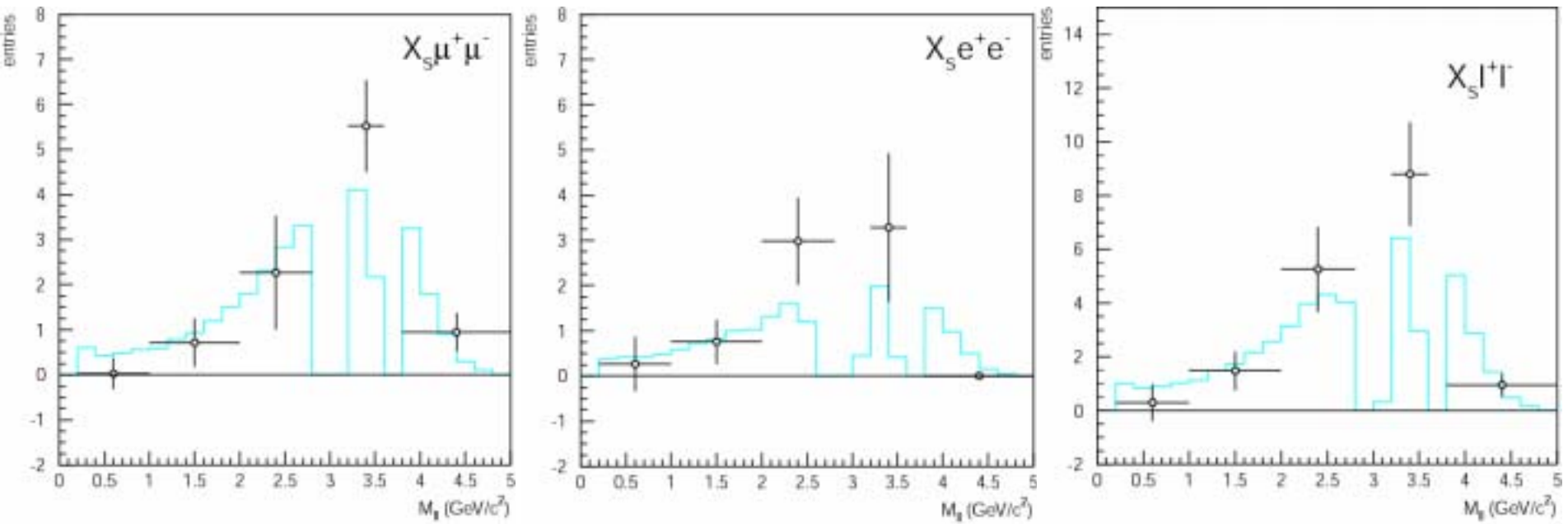
TODAY(May 18)

M(Xs) Distribution



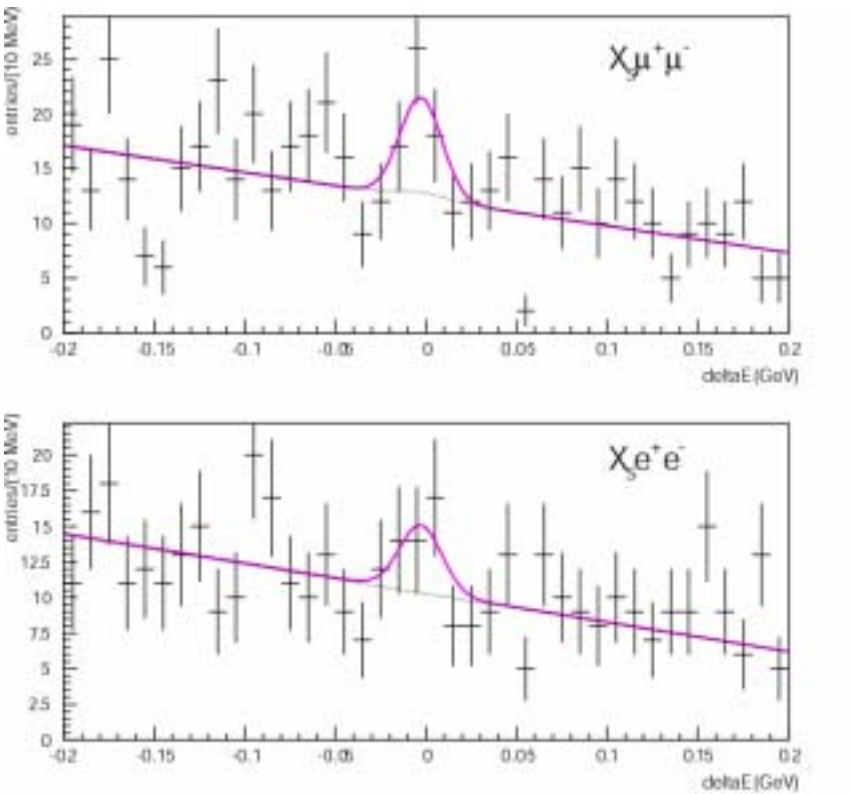
With the higher statistics, more information will be obtained from M(Xs) distribution.

M(ll) Distribution



With the higher statistics, more information will be obtained from M(Xs) distribution.

ΔE distribution and fit results



ΔE distribution fit for cross check.

Mode	#signal
$X_s e^+ e^-$	13.6 ± 7.8
$X_s \mu^+ \mu^-$	20.8 ± 8.5
$X_s \ell^+ \ell^-$	31.9 ± 12.5

Signal yields are consistent with the Mbc fit results.