Rare decays at Super-KEKB

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KEK — High Energy Accelerator Research Organization

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- $B \to \gamma X_s$ (inclusive and exclusive)
- $B \to \ell\ell X_s$ (inclusive and exclusive)
- $B \to \nu\nu K$
- $B \to \tau\nu_\tau$

Super-KEKB

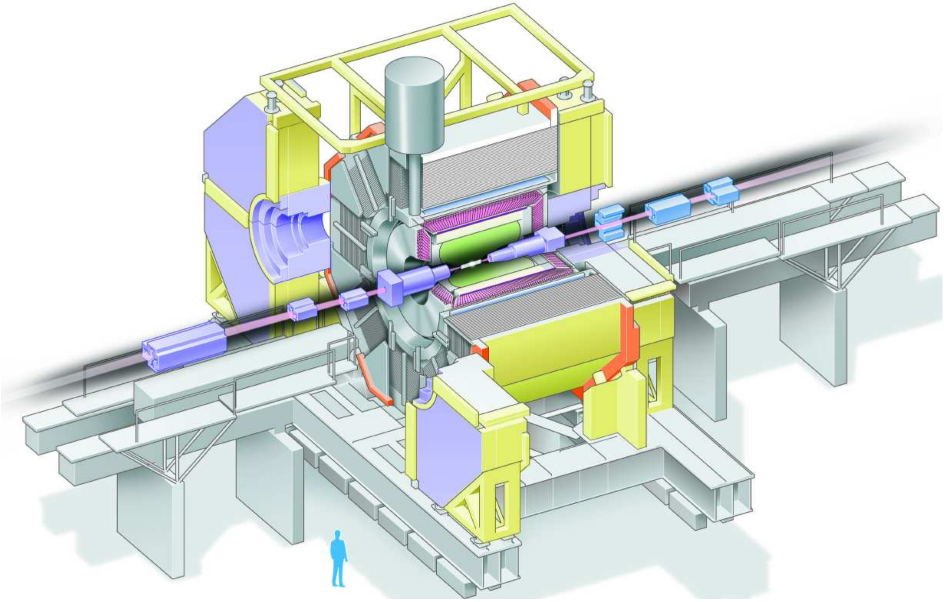
More about Super-KEKB in Katayama-san's "Belle Workshop Report" at the Monday Plenary Session.

All plots and numbers are taken from Nakao-san and Nishida-san's talks at the 5th Workshop at Izu.

See http://belle.kek.jp/superb/

Super-Belle

- Better Particle ID
- Better Calorimeter
- But much more beam back-ground



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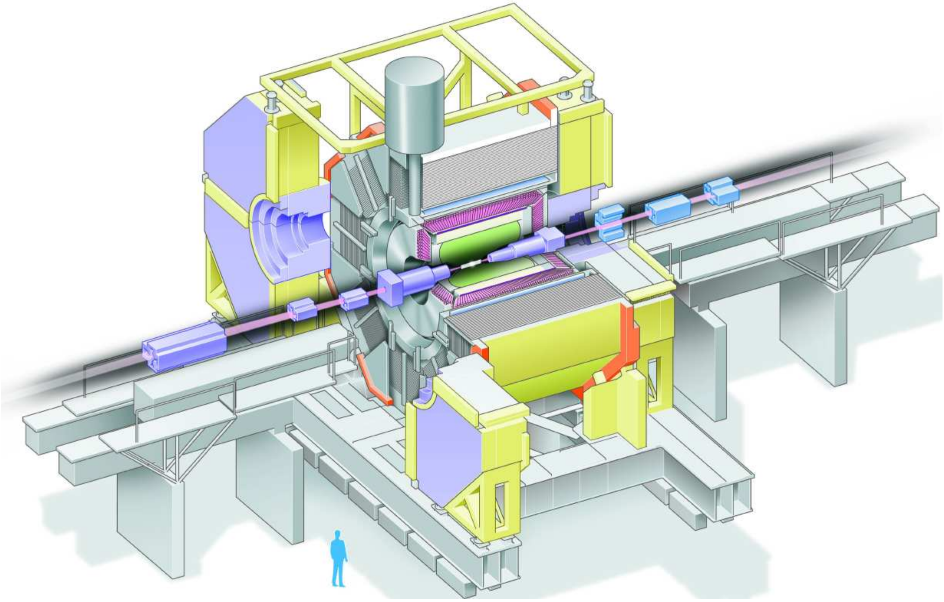
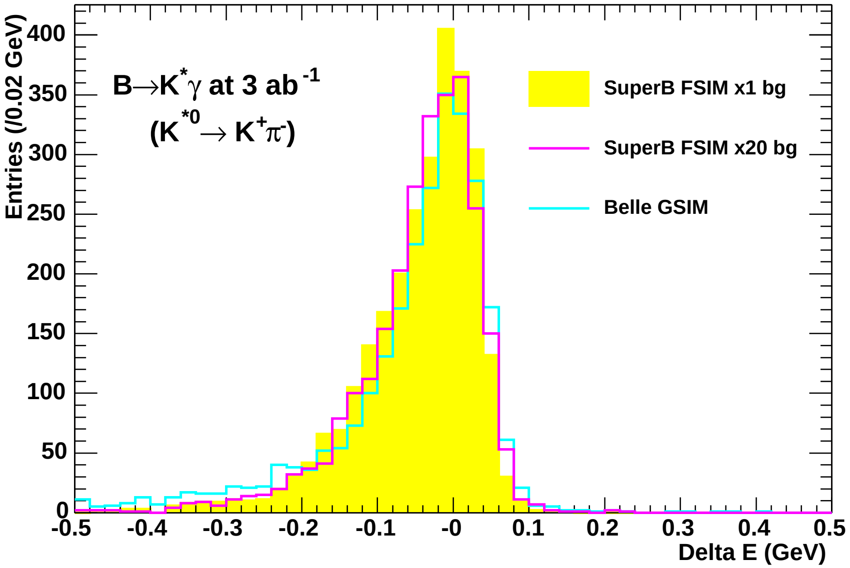
Some results are extrapolated from present yields, some come from FSIM.



Similar efficiency for $K^*\gamma$



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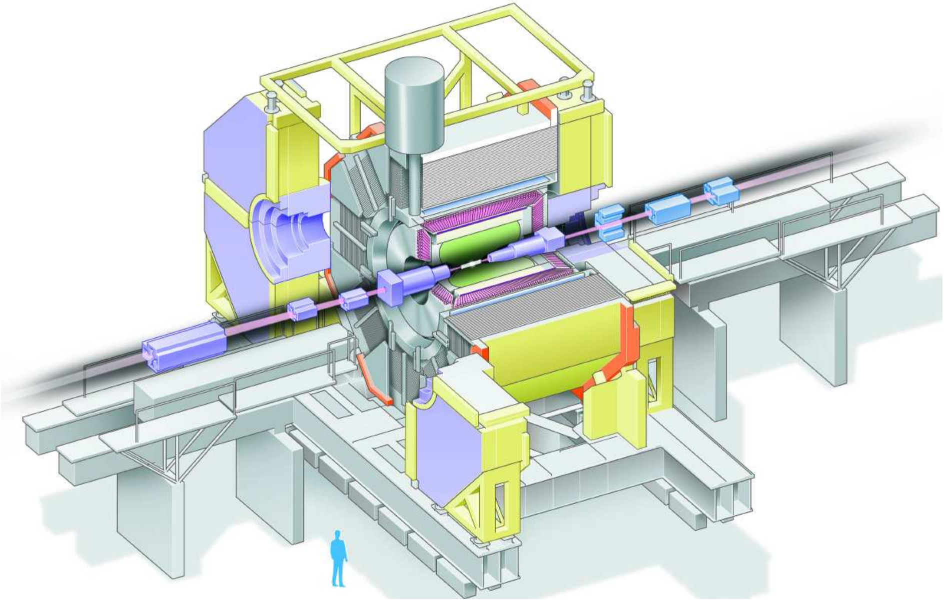


$3\,\mathrm{ab}^{-1}$ and $30\,\mathrm{ab}^{-1}$ are used as benchmarks.

$$b \longrightarrow s\gamma$$

Shopping List:

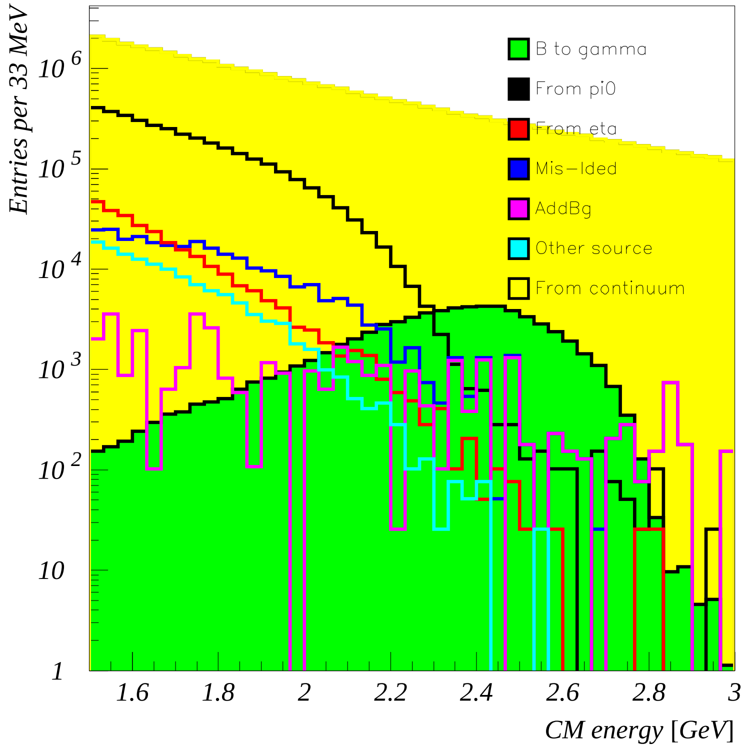
- Inclusive branching fraction
- Direct CP asymmetries
- Mixing-induced CP asymmetries

$+$ Search for exclusive modes (also $b \to d\gamma$)...

Inclusive $b \to \gamma s$

- Measure γ E^* spectrum
- Subtract continuum
- Subtract B backgrounds
- Extract BR from sensitivity region. CLEO $E^* > 2.0\,\mathrm{GeV}$.

Hard to extrapolate to high $\mathcal{L}$: Beam background increases. Error dominated by OFF-resonance statistics.



No cuts. $140\ \mathrm{fb}^{-1}$.

Wild guess: $E^* > 1.5\,\mathrm{GeV}$ at $\mathcal{O}(1\,\mathrm{ab}^{-1})$
Small model error, 1–2% γ eff. error, small stat. error
$\Rightarrow \mathcal{O}(5\%)$ total error?

CP in Semi-Inclusive $B \to \gamma X_s$

$140\ \mathrm{fb}^{-1}$ (LP'03, preliminary), $m_{X_s} < 2.1\ \mathrm{GeV}$:

$A_{\mathrm{CP}}(B \to X_s\gamma) = (-0.4 \pm 5.1 \pm 3.8)\ \%$

Can we achieve 0.6% (max. SM prediction)?

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Present systematics are:

- 0.8% signal shape $\leftarrow$ inclusive analysis
- 2.0% from A_{CP} in backgrounds $\to$ will improve with measurements
- 2.9% Charge asymmetry in cuts $\to$ scales with statistics

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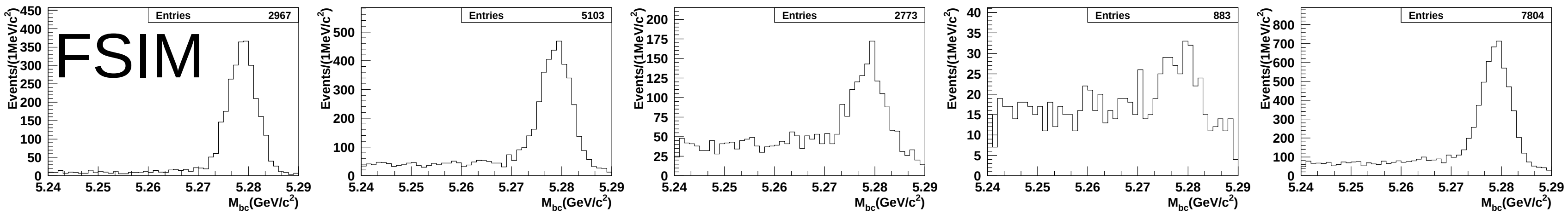
Can we achieve 0.6% (max. SM prediction)?

Future systematics may be:

- $3\ \mathrm{ab}^{-1}$: $(\pm 1.1 \pm 0.8 \pm 0.3)\,\%$
- $30\ \mathrm{ab}^{-1}$: $(\pm 0.4 \pm 0.3 \pm 0.3)\,\%$
- Last error for model-dependence (?)



$K\pi\gamma$ $K2\pi\gamma$ $K3\pi\gamma$ $K4\pi\gamma$ $3K(\pi)\gamma$

and more?

Time-dependent CP in $B \to \gamma X_s$

Copy $\sin 2\phi_1$ analysis for radiative decays:

- $B \to K^*(K^0_S \pi^0)\gamma$
  - CP eigenstate
  - needs K^0_S vertex

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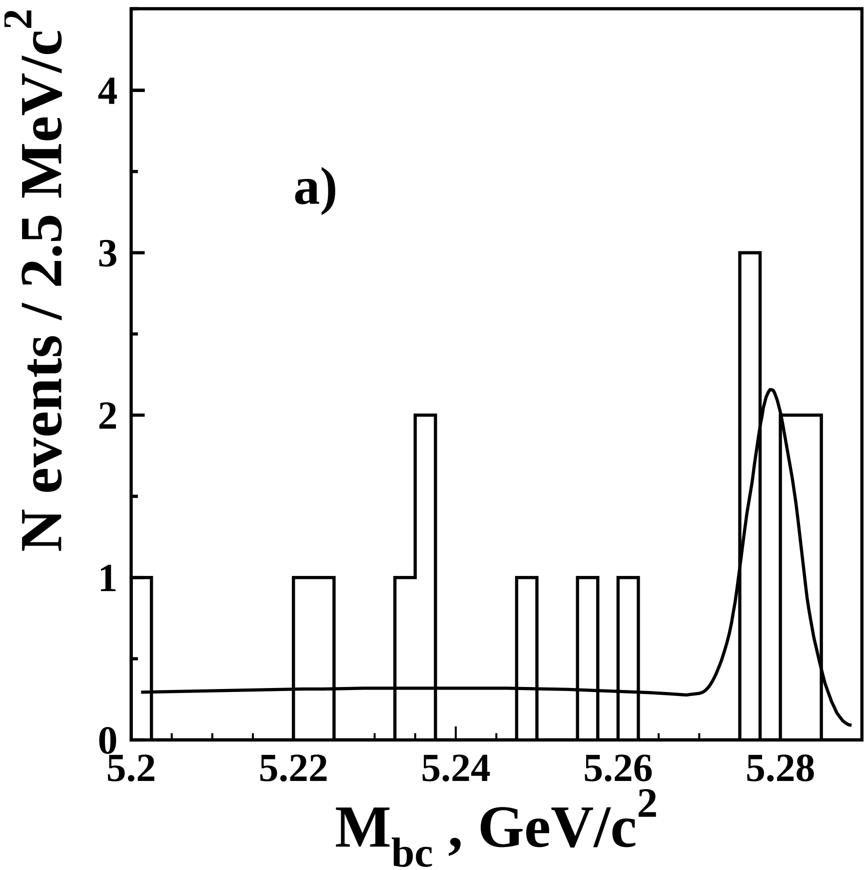
Copy $\sin 2\phi_1$ analysis for radiative decays:

- $B \to K^*(K^0_S\pi^0)\gamma$
  - CP eigenstate
  - needs K^0_S vertex
- $B \to \phi K^0_S\gamma$
  - Mixed CP state $\to$ angular analysis
  - Very clean
  - 100 events at $3\ \mathrm{ab}^{-1}$



$B \to \phi K^0_S\gamma$: 3σ at $90\ \mathrm{fb}^{-1}$.

$b \to \ell\ell s$

Shopping List:

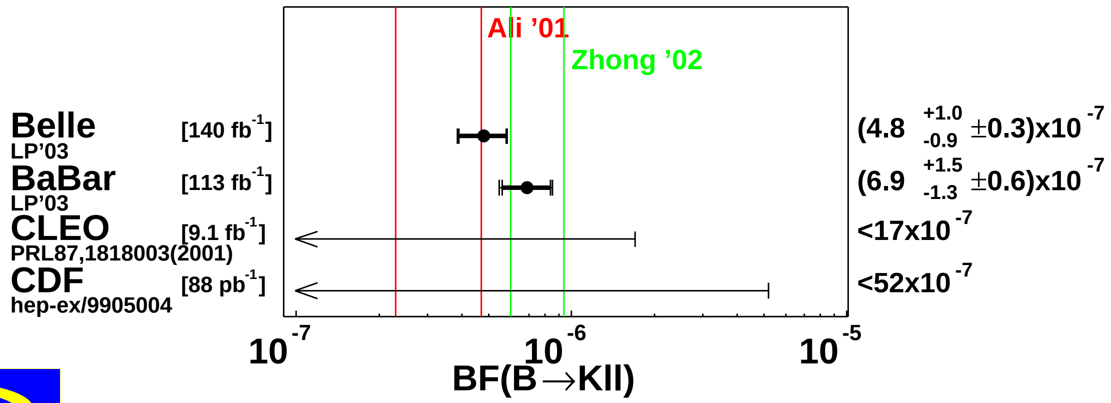
- Forward-backward charge asymmetry
- ee versus $\mu\mu$

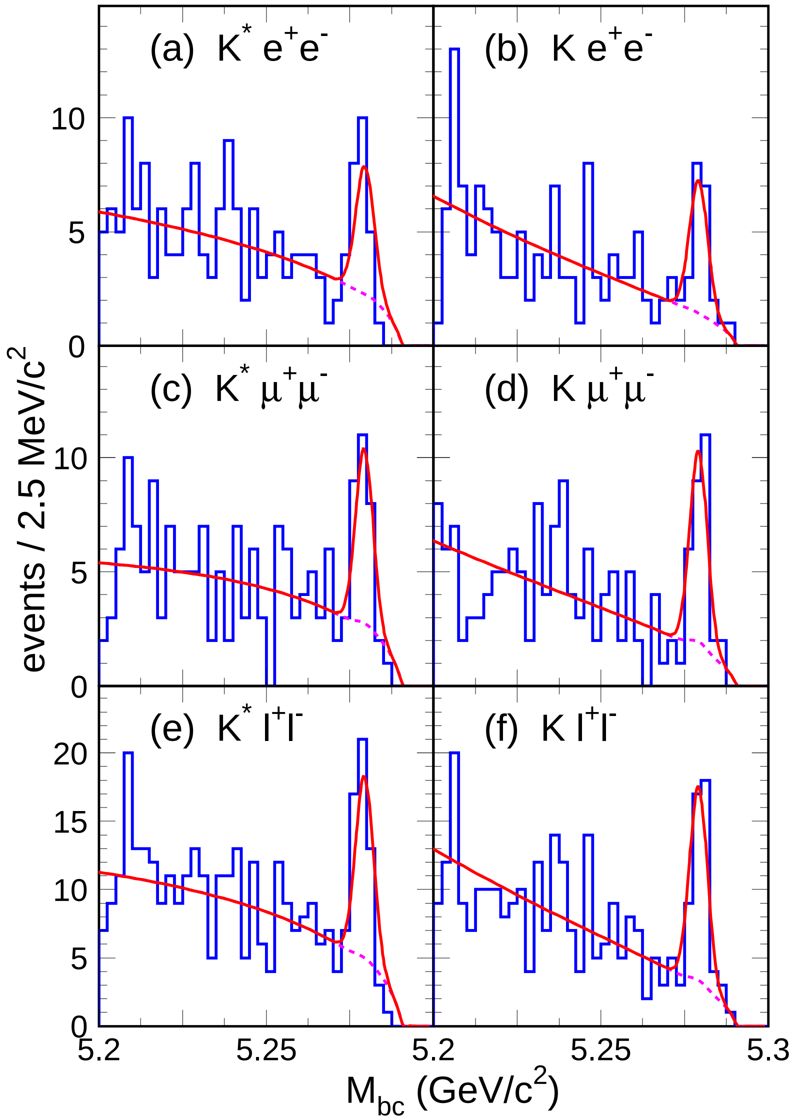
\+ Search for exclusive modes (also $b \to \ell\ell d$)...

$B \to K^{(*)}\ell\ell$ today

First observation of $B \to K^*\ell\ell$ (LP'03, $140\ \mathrm{fb}^{-1}$)

- $\mathrm{BR}\,(B \to K^*\ell\ell) = \left(11.5\,^{+\,2.6}_{-\,2.4} \pm 0.8 \pm 0.2\right)\cdot 10^{-7}$
- $\mathrm{BR}\,(B \to K\ell\ell) = \left(\ 4.8\,^{+\,1.0}_{-\,0.9} \pm 0.3 \pm 0.1\right)\cdot 10^{-7}$





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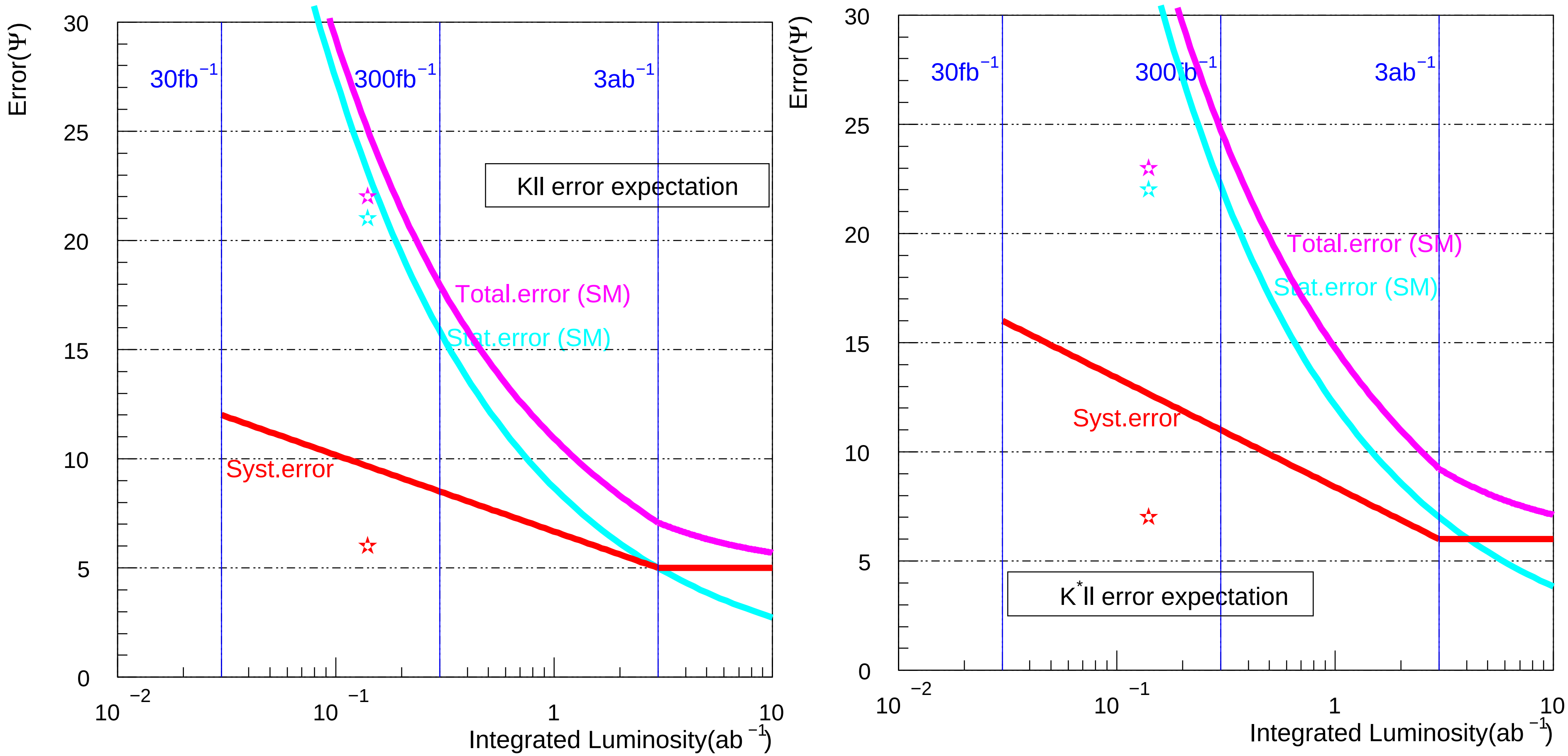
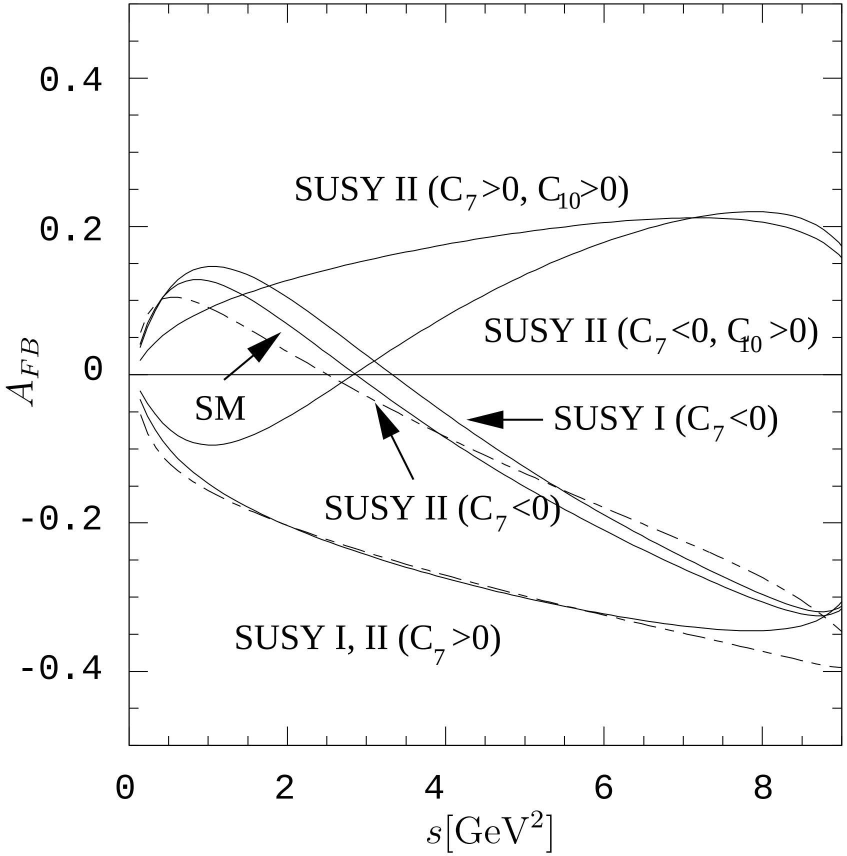
$B \to K^{(*)}\ell\ell$ extrapolation

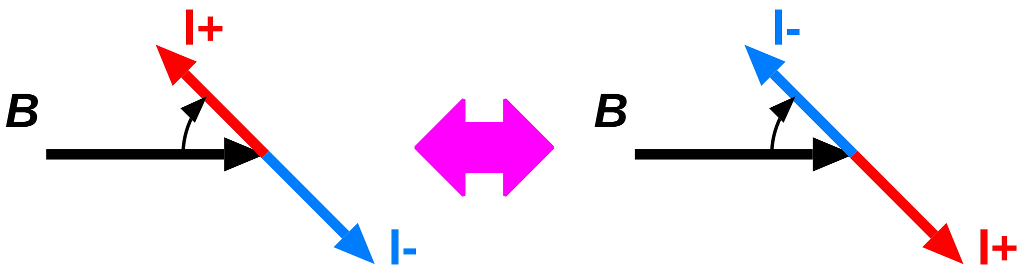


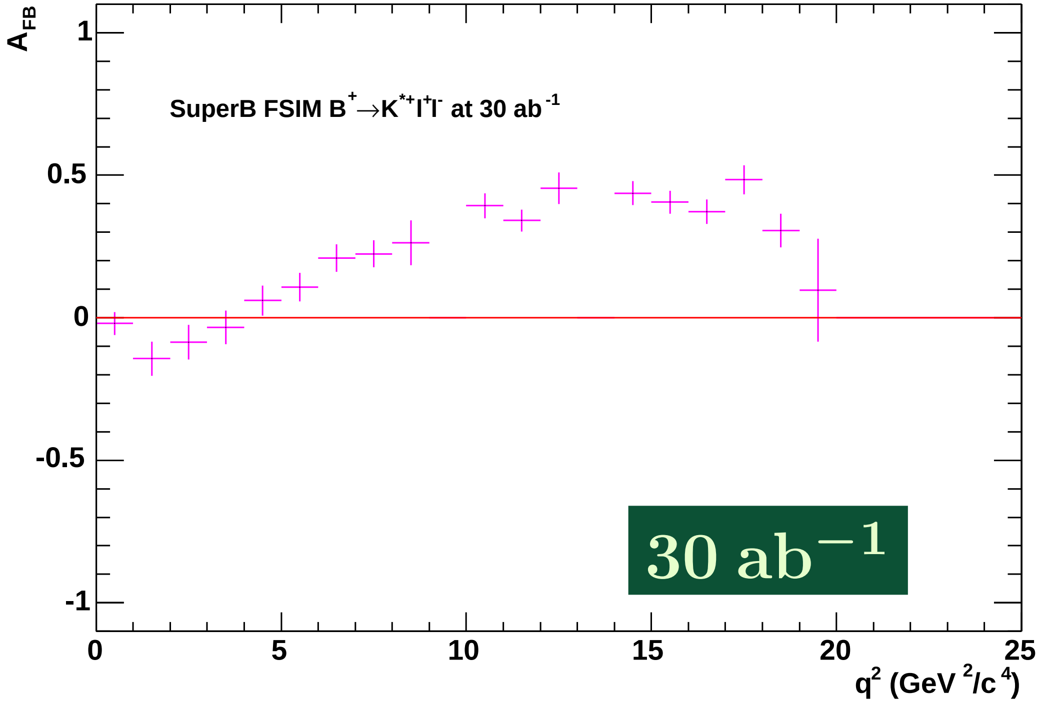
Extrapolations from two years ago.
Stars indicate where we are now $\longrightarrow$ much better systematic error

$B \to K^* \ell\ell$ FB asymmetry



l+l- rest frame





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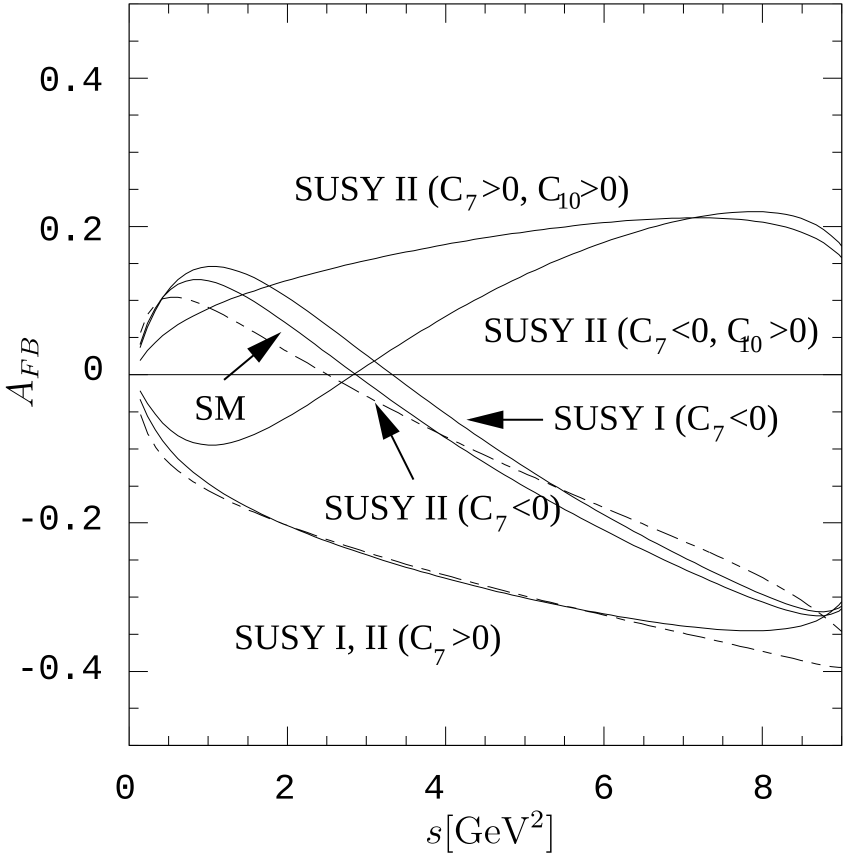

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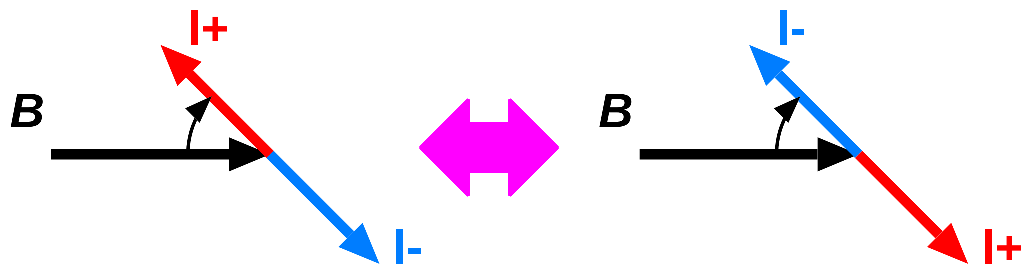

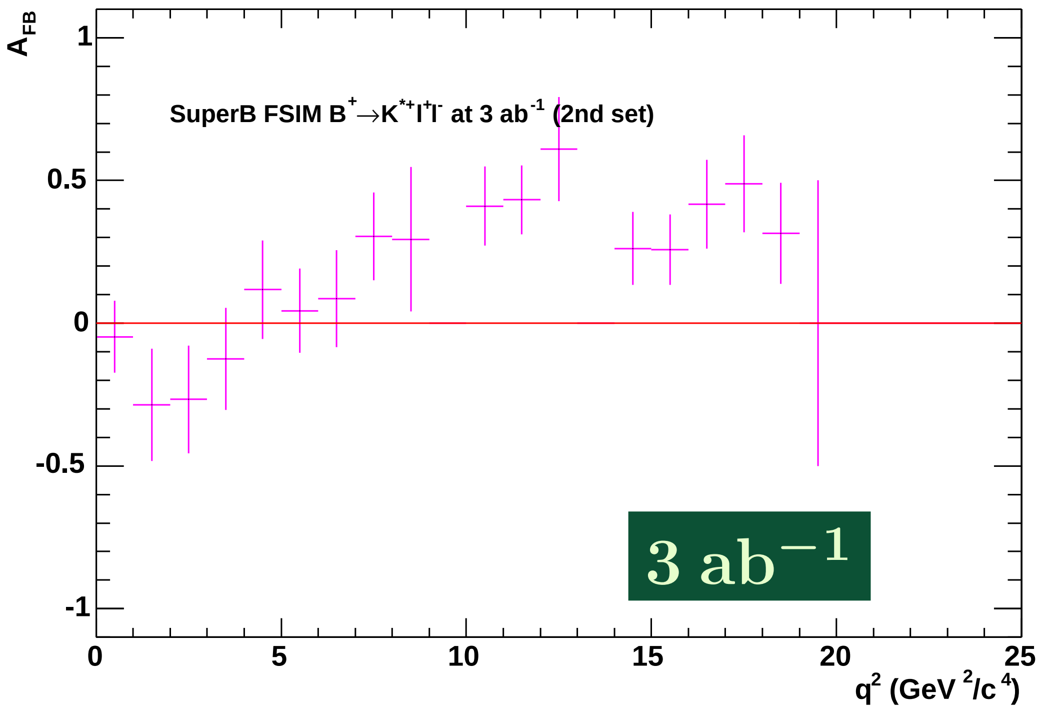

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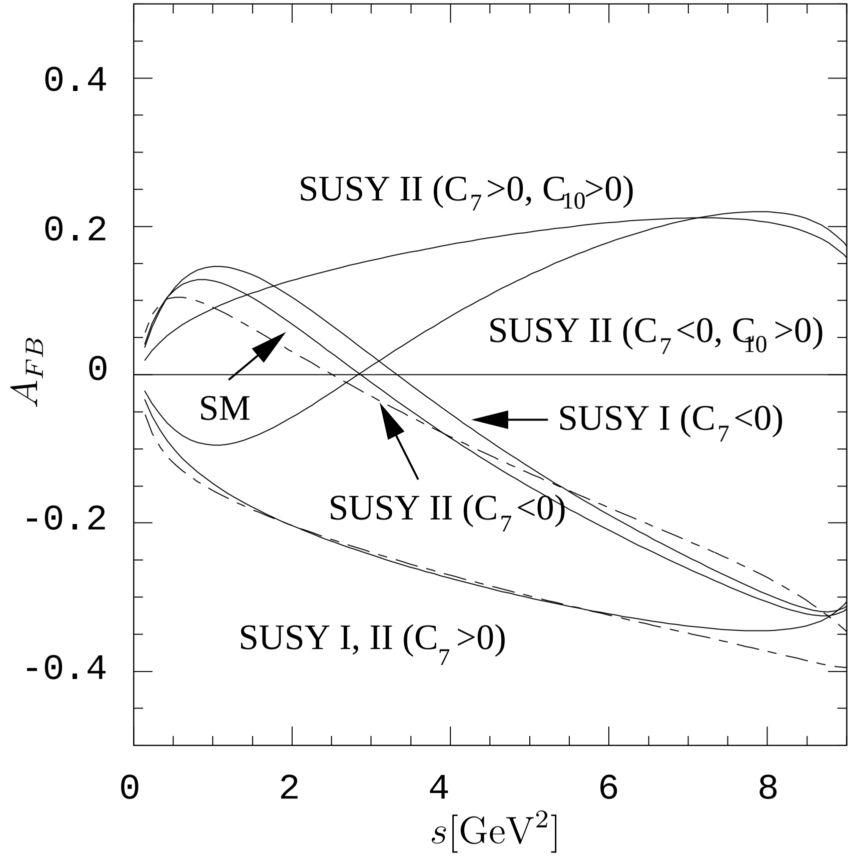

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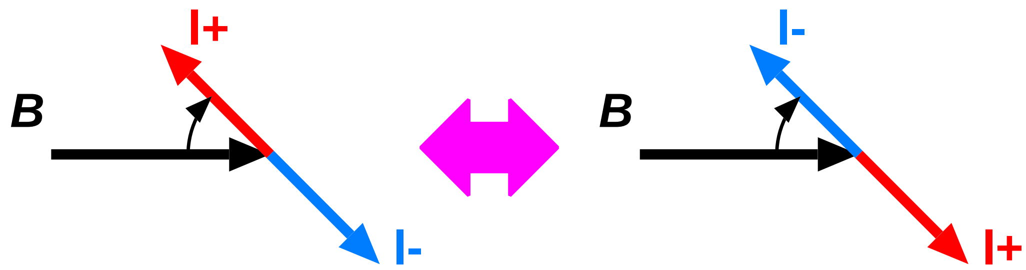

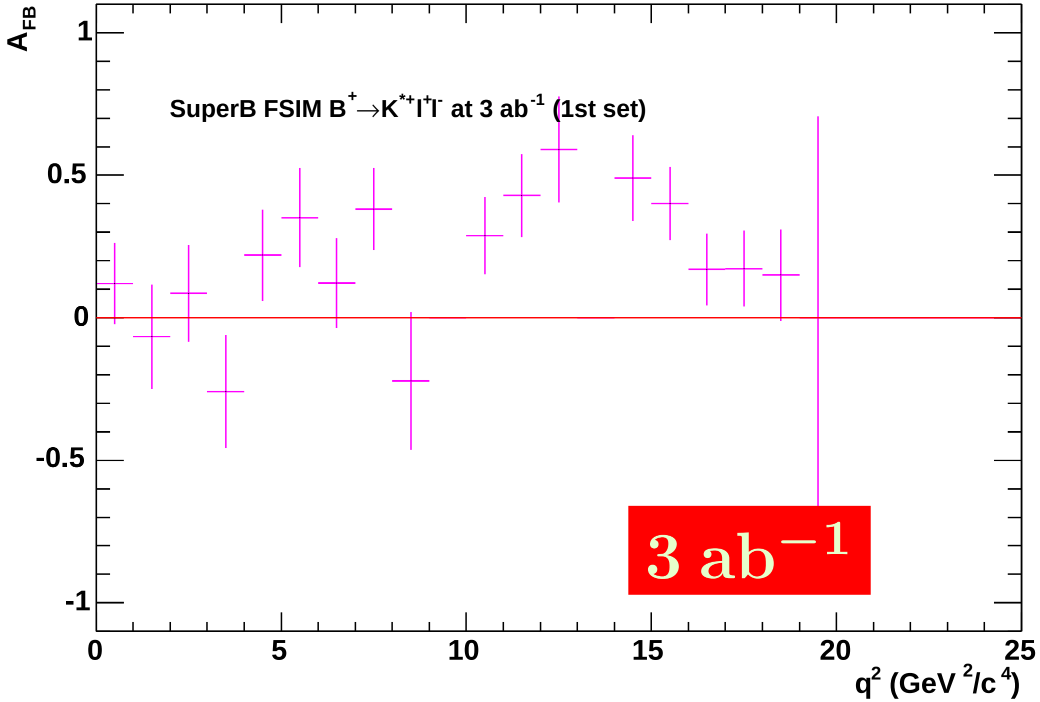

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$B \to Kee$ versus $B \to K\mu\mu$

Hiller & Krüger, [hep-ph/0310219]: SM: $\mathrm{BR}(Kee) = \mathrm{BR}(K\mu\mu)$
New Physics may make it different

Now:

$$\left.\begin{array}{lcl} \mathrm{BR}(Kee) & = & \left(4.8\,^{+1.5}_{-1.3} \pm 0.3 \pm 0.1\right) \cdot 10^{-7} \\ \mathrm{BR}(K\mu\mu) & = & \left(4.8\,^{+1.2}_{-1.1} \pm 0.3 \pm 0.2\right) \cdot 10^{-7} \end{array}\right\} \begin{array}{l} R < 1.8 \\ (90\%\ \text{CL}) \end{array}$$

Future:

$$\begin{array}{rcl} 3\,\mathrm{ab}^{-1} & \longrightarrow & R < 1.18 \\ 30\,\mathrm{ab}^{-1} & \longrightarrow & R < 1.06 \end{array}$$

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$$B \to K\nu\nu$$

$$B \to \tau\nu_\tau$$

See Nishida-san's talk at Izu for details

http://belle.kek.jp/superb/

$B \to K\nu\nu$ and $B \to \tau\nu_\tau$

$B \to K\nu\nu$

- $\mathrm{BR} = 5 \cdot 10^{-6}$ (theory)
- $\mathrm{BR} < 7 \cdot 10^{-5}$ (BaBar)
- Clean one-loop diagram
- Sensitive to New Physics

$B \to \tau\nu_\tau$

- $\mathrm{BR} = 7 \cdot 10^{-5}$ (theory)
- $\mathrm{BR} < 4.1 \cdot 10^{-4}$ (BaBar)
- Clean measure of $f_B \to V_{td}$ from $\Delta m_s / \Delta m_d$
- Limit on charged Higgs mass

$\to$ Different motivations.

$B \to K\nu\nu$ and $B \to \tau\nu_\tau$

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$\to$ Different motivations.

Similar analysis:
One track and nothing else on one side,
Fully reconstructed B on the other side.

$B \to K\nu\nu$ and $B \to \tau\nu_\tau$

Very preliminary study.

Assumes present full-reconstruction efficiency (0.1%).
This is going to improve a lot (but at what price?).

$B \to K\nu\nu$	$B \to \tau\nu_\tau$
• Probably nothing at $3\ \mathrm{ab}^{-1}$	• No hope at $3\ \mathrm{ab}^{-1}$
• Could be seen $30\ \mathrm{ab}^{-1}$	• Could be seen $30\ \mathrm{ab}^{-1}$

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Conclusions

At $3\ \mathrm{ab}^{-1}$ we expect:

- Almost full $b \to \gamma$ spectrum
- 100 $B \to \phi K^0_S$ events
- May see A_{FB} in $B \to K^* \ell\ell$

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At $30\ \mathrm{ab}^{-1}$ we expect:

- $B \to X_s \gamma\ \Delta A_{\mathrm{CP}} < 0.6\%$
- Clearly see A_{FB} in $B \to K^* \ell\ell$
- Maybe $B \to K\nu\nu$ and $B \to \tau\nu_\tau$

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Hear about what Hadron Colliders can do on Friday Morning