Inclusive and Exclusive $b \rightarrow s,d\ ll$

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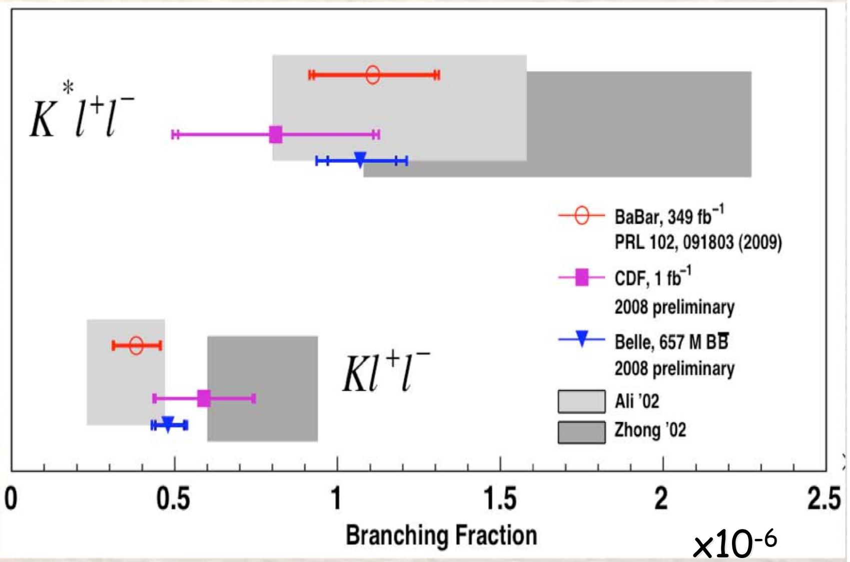
Introduction

- Using BABAR measurements for exclusive $B \rightarrow K^{(*)} \ell^+ \ell^-$ modes (349.2 fb^{-1}) and for inclusive $B \rightarrow X_s \ell^+ \ell^-$ a sum of exclusive modes (81.9 fb^{-1}), I extrapolate expectations to 75 ab^{-1} at SuperB
- I will discuss exclusive and inclusive methods, I scale statistical errors of previous BABAR measurements by $\sqrt{L}$
- Since the BABAR detector will be used to a large extent many systematic errors will be similar
- With high statistics selections can be tuned to lower systematic errors
  ➔ I assume improvement by 1.3-1.5 for exclusive and ~2 for inclusive



- I focus on the $q^2 < 6$ GeV^2 region, but also give extrapolations for the entire q^2 region (we will measure also high-q^2 region)

Can reliable predictions be made for high-q^2 region in inclusive mode?

Exclusive $B \to K^{(*)} \ell^+ \ell^-$

- We reconstruct $B \to K^{(*)} \ell^+ \ell^-$ in 12 exclusive final states, K^+, K^0_S, $K^+\pi^-$, $K^+ \pi^0$, $K^0_S \pi^+$ plus e^+e^- or $\mu^+\mu^-$
- We select signal with neural networks, 4 separate NN in each mode (2 q^2 bins, $B\bar{B}$ and $q\bar{q}$) low: $0.1 \leq q^2 \leq 7.02$ (6.25) GeV^2,
  high: $10.24 \leq q^2 \leq 12.96$ GeV^2 & $q^2 \geq 14.06$ GeV^2

➔ for angular analysis low q^2 region is reduced to minimize leakage from $B \to J/\psi K^{(*)}$ and $B \to \psi(2S) K^{(*)}$

- Inputs into consist of event shape variables, vertex variables, kinematic constraints and angular distributions

PRL 102, 091803 (2009),
PRD 79, 031102 (2009)

- For the final selection we cut on ΔE and fit m_{ES} distribution

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

$$m_{ES} = \sqrt{E^{*2}_{beam} - \vec{p}^{\,*2}_B}$$

- Efficiencies in individual modes range from 5-22%
- We are updating analysis with full BABAR data set, improved particle ID, use boosted decision trees ➔ expect ~50% more signal yield

Exclusive $B \rightarrow K^{(*)} \ell^+ \ell^-$

- Events yields in 349.2 fb^{-1}: $B \rightarrow K \ell^+ \ell^-$: 60±11 (all q^2), 31±7 (low q^2)
  $B \rightarrow K^* \ell^+ \ell^-$: 74±13 (all q^2), 43±11 (low q^2)

- Events yields in 425 fb^{-1}: $B \rightarrow K \ell^+ \ell^-$: 90±14 (all q^2), 47±9 (low q^2)
  $B \rightarrow K^* \ell^+ \ell^-$: 110±16 (all q^2), 65±13 (low q^2)

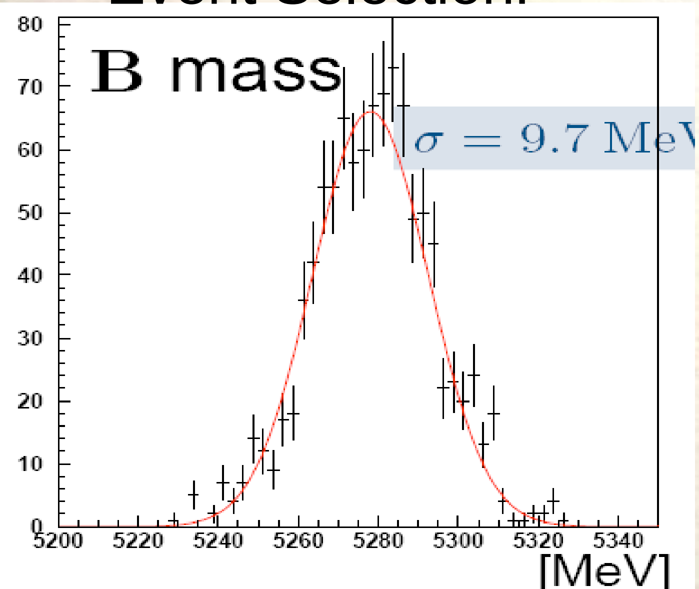
- Yields in 75 ab^{-1}: $B \rightarrow K \ell^+ \ell^-$: $(1.59 \pm 0.019) \times 10^4$ (all q^2), $(8.3 \pm 0.12) \times 10^3$ (low q^2)
  $B \rightarrow K^* \ell^+ \ell^-$: $(1.94 \pm 0.021) \times 10^4$ (all q^2), $(11.5 \pm 0.17) \times 10^3$ (low q^2)

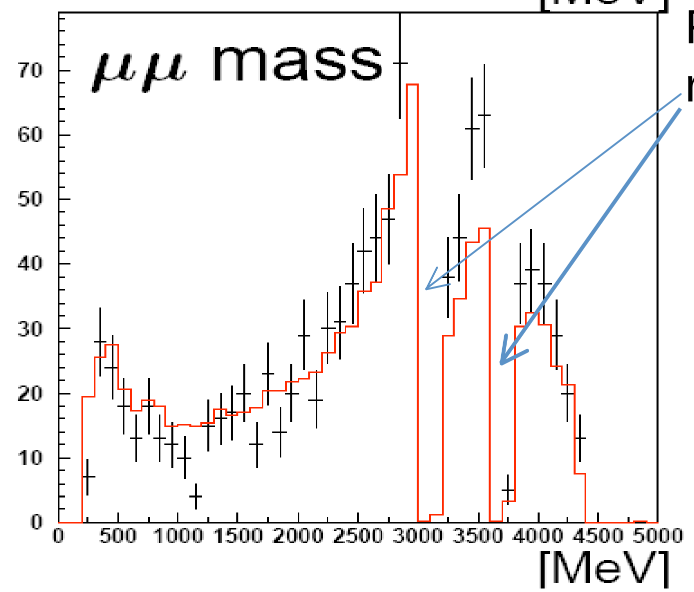
- This allows us to measure observables in the $0.1 \leq q^2 \leq 6$ GeV^2 region in 12 bins with ~1000 events per bin ➔ e.g. determine $\mathcal{A}_{FB}$ zero crossing

- In 75 ab^{-1} most measurements will be limited by systematic errors
  ➔ in low q^2 region statistical error is ~5% per bin (12 bins)
  ➔ systematic errors in rates are 3-4% (4-5%) for all 12 bins, may be reducible slightly
  ➔ systematic errors in asymmetries are lower 1-4% (see later)

Expectations of $B \to K^{(*)} \ell^+ \ell^-$ in LHCb

Event Selection:

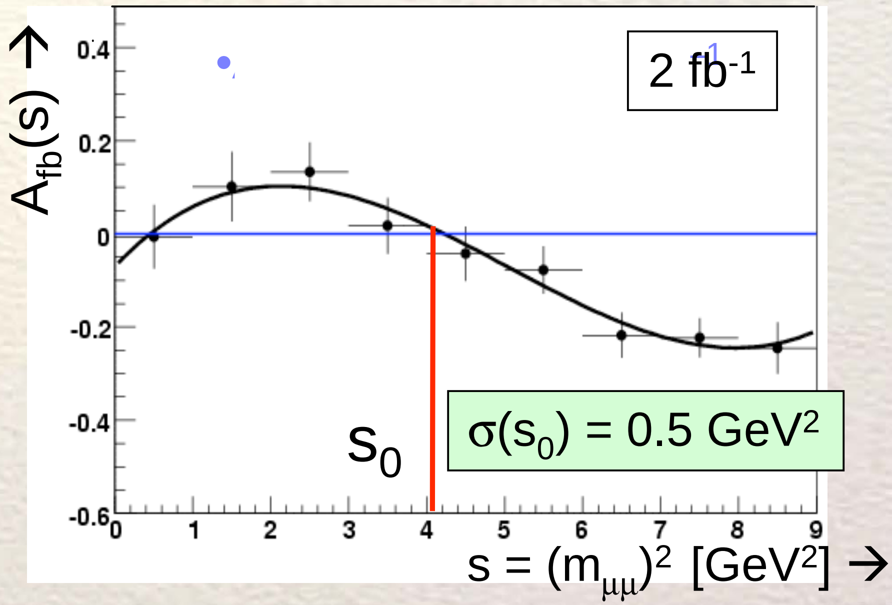




Remove resonances

- LHCb focuses on $B^0 \to K^{*0} \mu^+ \mu^-$

Channel	Yield (2 fb^{-1})	BG (2 fb^{-1})
$B \to K^* \mu^+ \mu^-$	7200+-2200 (BR)	1770+-310



Systematic study:

- Selection should not distort $m^2_{\mu\mu}$
- s_0 point to first order not affected

- LHCb can measure $\mathcal{A}_{FB}$, $\mathcal{F}_L$, $\mathcal{A}_{CP}$ & (partial) $\mathcal{B}$

Inclusive $B \to X_s \ell^+ \ell^-$: Signal & Backgrounds

- Prediction: $\mathcal{B}(B \to X_s e^+ e^-) = (6.89 \pm 1.01) \times 10^{-6}$ Ali et al, PRD 66, 034002 (2002)
  $\mathcal{B}(B \to X_s \mu^+ \mu^-) = (4.15 \pm 0.70) \times 10^{-6}$
- Measurements: $\mathcal{B}(B \to X_s e^+ e^-) = (4.7 \pm 1.3) \times 10^{-6}$ PDG 2008
  $\mathcal{B}(B \to X_s \mu^+ \mu^-) = (4.3 \pm 1.2) \times 10^{-6}$
- Dominant backgrounds from double B, D semileptonic decays (e or μ)
  - $\mathcal{B}(B^+ \to \overline{X}_c \ell^+ \nu) \times \mathcal{B}(B^- \to X_c \ell^- \nu) = (1.07 \pm 0.05) \times 10^{-2}$
  - $\mathcal{B}(B^0 \to X^-_c \ell^+ \nu) \times \mathcal{B}(B^0 \to X^+_c \ell^- \nu) = (1.21 \pm 0.06) \times 10^{-2}$
  - $\mathcal{B}(B^+ \to \overline{X}_c \ell^+ \nu) \times \mathcal{B}(\overline{D}^0 \to X_s \ell^- \nu) = (1.65 \pm 0.08) \times 10^{-2}$
  - $\mathcal{B}(B^0 \to X^-_c \ell^+ \nu) \times \mathcal{B}(D^- \to X_s \ell^- \nu) = (0.72 \pm 0.04) \times 10^{-2}$
  - $\mathcal{B}(D^+ \to \overline{X}_s \ell^+ \nu) \times \mathcal{B}(D^- \to X_s \ell^{+-} \nu) \times f_{D+} = (0.58 \pm 0.06) \times 10^{-2}$
  - $\mathcal{B}(D^0 \to \overline{X}_s \ell^+ \nu) \times \mathcal{B}(\overline{D}^0 \to X_s \ell^- \nu) \times f_{D0} = (0.24 \pm 0.05) \times 10^{-2}$
  - $\mathcal{B}(D^+_S \to \overline{X}_s \ell^+ \nu) \times \mathcal{B}(D^-_S \to X_s \ell^- \nu) \times f_{Ds} = (0.06 \pm 0.045) \times 10^{-2}$
- Before cuts background from sl decays is 2-3.5 (4) orders of magnitude bigger than signal for individual (summed) backgrounds
  ➔this is of course over large ΔE-m_{ES} region

Inclusive $B \to X_s \ell^+\ell^-$: Events in BABAR

- In addition, we get backgrounds from $B \to J/\psi X_s$ & $B \to \psi(2s) X_s$ modes
  - $\mathcal{B}(B \to J/\psi X_s) \times \mathcal{B}(\psi \to \ell^+\ell^-) = (6.5 \pm 0.2) \times 10^{-4}$
  - $\mathcal{B}(B \to \psi(2S) X_s) \times \mathcal{B}(\psi(2S) \to \ell^+\ell^-) = (0.24 \pm 0.016) \times 10^{-4}$
- These are removed by cuts around the J/ψ and $\psi(2S)$ masses
  ➔we need to recover bremsstrahlungs photons to reduce leakage outside J/ψ and $\psi(2S)$ mass regions
- For the BABAR luminosity we expect signal yields before cuts
  - (4400 ± 600) e^+e^- events
  - (4000 ± 560) $\mu^+\mu^-$ events

  $\leftrightarrow$ $(2.66 \pm 0.13) \times 10^7$ sl backgrounds (in large ΔE-m_{ES} region)
- For 75 ab^{-1} at SuperB we expect signal yields before cuts of
  - $(7.8 \pm 1.1) \times 10^5$ e^+e^- events
  - $(7.1 \pm 1.0) \times 10^5$ $\mu^+\mu^-$ events

  $\leftrightarrow$ $(4.69 \pm 0.24) \times 10^9$ sl backgrounds (in large ΔE-m_{ES} region)

Inclusive $B \to X_s \ell^+\ell^-$: Events in BABAR

- 2 analysis strategies exist to reduce these enormous backgrounds
- A sum over exclusive final states (SEM)
  - Pros: ➔ Use of kinematic constraints ΔE and m_{ES}
    large background suppression factor for m_{ES}> 5.2 GeV
    ➔ Select $B \to X_s \ell^+\ell^-$ (no $X_d \ell^+\ell^-$) with reasonable ε_{rec}~few %
    ➔ large statistics, study asymmetries rates in individual FS
  - Cons: ➔ leave out final states (high multiplicity, multiple π^0, K^0_L)
    ➔ efficiency decreases with increasing # particles
    ➔ large model error (~15%)
- Reconstruction of one B meson in hadronic or semileptonic final states and an e^+e^- or $\mu^+\mu^-$ pair in the recoil (RM)
  - Pros: ➔ efficiency is independent of multiplicity, but is small
    ➔ Remove sl backgrounds from opposite B's, and DD
    ➔ Reconstruct $B \to (X_s + X_d) \ell^+\ell^-$, need to subtract $X_d \ell^+\ell^-$
  - Cons: ➔ Need to eliminate sl background from same B
    ➔ lower efficiency > factor of 10 lower statistics

Sum of Exclusive $B \to X_s \ell^+ \ell^-$ Decays

- Decomposition of $B^+ \to X^+_s \ell^+ \ell^-$ & $B^0 \to X^0_s \ell^+ \ell^-$ into exclusive final states

X_s Topology	$B^+ \to X_s e^+ e^-$	$B^+ \to X_s \mu^+ \mu^-$
$K^+\pi^0$	0.139	0.158
$K^+\pi^+\pi^-$	0.159	0.148
$K^+\pi^0\pi^0$	0.033	0.033
$K^+\pi^+\pi^-\pi^0$	0.079	0.071
$K^+\pi^0\pi^0\pi^0$	0.015	0.016
$K^+\pi^+\pi^-\pi^+\pi^-$	0.004	0.004
$K^+\pi^+\pi^-\pi^0\pi^0$	0.013	0.013
$K^+\pi^0\pi^0\pi^0\pi^0$	0.004	0.002
$K^+X[\geq 5(\pi^\pm \text{ or } \pi^0)]$	0.012	0.009
$K^+X[\geq 2\pi^0]$	0.072	0.069
$K^0_S\pi^+$	0.131	0.139
$K^0_S\pi^+\pi^0$	0.087	0.084
$K^0_S\pi^+\pi^-\pi^+$	0.012	0.010
$K^0_S\pi^+\pi^0\pi^0$	0.009	0.010
$K^0_S\pi^+\pi^-\pi^+\pi^0$	0.010	0.009
$K^0_S\pi^+\pi^0\pi^0\pi^0$	0.004	0.003
$K^0_S X[\geq 5(\pi^\pm \text{ or } \pi^0)]$	0.004	0.004
$K^0_S X[\geq 2\pi^0]$	0.017	0.016
$K^0_L X$	0.264	0.266

X_s Topology	$B^0 \to X_s e^+ e^-$	$B^0 \to X_s \mu^+ \mu^-$
$K^+\pi^-$	0.258	0.289
$K^+\pi^-\pi^0$	0.173	0.184
$K^+\pi^-\pi^+\pi^-$	0.024	0.018
$K^+\pi^-\pi^0\pi^0$	0.020	0.018
$K^+\pi^-\pi^+\pi^-\pi^0$	0.025	0.018
$K^+\pi^-\pi^0\pi^0\pi^0$	0.008	0.007
$K^+X[\geq 5(\pi^\pm \text{ or } \pi^0)]$	0.009	0.007
$K^+X[\geq 2\pi^0]$	0.036	0.030
$K^0_S\pi^0$	0.070	0.077
$K^0_S\pi^+\pi^-$	0.073	0.074
$K^0_S\pi^0\pi^0$	0.016	0.016
$K^0_S\pi^+\pi^-\pi^0$	0.044	0.036
$K^0_S\pi^0\pi^0\pi^0$	0.007	0.006
$K^0_S\pi^+\pi^-\pi^+\pi^-$	0.003	0.002
$K^0_S\pi^+\pi^-\pi^0\pi^0$	0.006	0.007
$K^0_S\pi^0\pi^0\pi^0\pi^0$	0.002	0.001
$K^0_S X[\geq 5(\pi^\pm \text{ or } \pi^0)]$	0.007	0.005
$K^0_S X[\geq 2\pi^0]$	0.034	0.033
$K^0_L X$	0.242	0.227

- Old analysis used $K^\pm$ or K^0_S with up to 3π's ➔ 60.7 B^+ & 64.2 B^0 decays
- New analysis will up to 4 π's ➔ 62.1 B^+ & 67.0 B^0 decays

Sum of Exclusive $B \to X_s \ell^+ \ell^-$ Decays

- We further use multivariate analyses to separate signal from backgrounds
  ➔ in the old analysis 9 variables were combined into a likelihood
  Optimization is M_X dependent and different for e^+e^- and $\mu^+\mu^-$
  ➔ in the new analysis we use boosted decision trees (16): 2 M_X bins, e^+e^- and $\mu^+\mu^-$, for $B\overline{B}$ and $q\overline{q}$
  Number of variables depends on final states no ΔE
- Efficiencies in the old analysis are $\varepsilon_{ee}=4.7\%$ and $\varepsilon_{\mu\mu}=2.2\%$
  ➔ expect higher efficiencies in new analysis, particularly for $\mu^+\mu^-$
- Extract signal from fit to m_{ES} distribution
  ➔ Observe (29.2 ± 8.3) e^+e^- and (11.2 ± 6.2) $\mu^+\mu^-$ events ($81.9\ fb^{-1}$) in signal region: $S/B\sim1$ for e^+e^- and $S/B \sim0.5$ for $\mu^+\mu^-$
  - All backgrounds are sufficiently small
  - Expect better performance in new analysis, ~270 events total
- For $75\ ab^{-1}$ in SuperB expect 48000 events, ~21000 for $q^2<6\ GeV^2$
  ➔ statistical errors of ~0.8% and <1.2%

Recoil Method

- The idea is to reconstruct one B-meson in hadronic final states or semileptonic final states
  - Use semi-exclusive reconstruction of hadronic modes
    $\bar{B} \to DY$ with $D=(D^0, D^+, D^{*0}, D^{*+})$, $D^* \to D\pi$, $D\gamma$
    $D^0 \to K^-\pi^+, K^-\pi^+\pi^0, K^-\pi^+\pi^-\pi^+, K^0_S\pi^+\pi^-,$
    $D^+ \to K^-\pi^+\pi^-, K^0_S\pi^+, K^-\pi^+\pi^-\pi^0, K^0_S\pi^+\pi^0$
    and $Y = k\,\pi^\pm + l\,K^\pm + m\,K^0_S + n\,\pi^0$
    with $k+l < 6$, $m< 3$, $n<3$, $k+l+m+n<6$ (~ 1100 final states)
    require $m_{ES} > 5.27$ and $|\Delta E| < 3\sigma_{\Delta E}$ (Aubert et al PRL 92, 071802, 2004)
    efficiency is 0.3% for B^0 and 0.5% for $B^\pm$
  - Use semileptonic decays $B \to D^{(*)}\ell\nu$ with D^*, D selection as above
    use $\cos\theta_{B-Dl}$ and p^*_ℓ to select tag
    efficiency is ~1.1% for $B^\pm$
  - Total B-reconstruction efficiency ε_{rec}=1.5%
- Look just for an $\ell^+\ell^-$ recoiling against reconstructed B

Recoil Method

- B reconstruction removes sl background from opposite B's & from $D\bar{D}$
- Same-B cascade sl background needs to be removed with cuts: $\ell^+\ell^-$ vertex, missing energy, cut on X_s<m_D (probably necessary)
- Residual background is subtracted bin-by-bin using $e\mu$ data sample
- Using $K^\pm$ and K^0_S selection and accounting for K^0_L, allows for subtraction of $X_d\ell^+\ell^-$ component
- From $\mathcal{B}(B\to X_d\ell^+\ell^-)/\mathcal{B}(B\to X_s\ell^+\ell^-)$ get $|V_{td}/V_{ts}|$
- Total efficiency is expected at ~0.3% (> factor 10 smaller than SEM)

➔ expect ~25±8 events in full BABAR sample (425 fb^{-1})

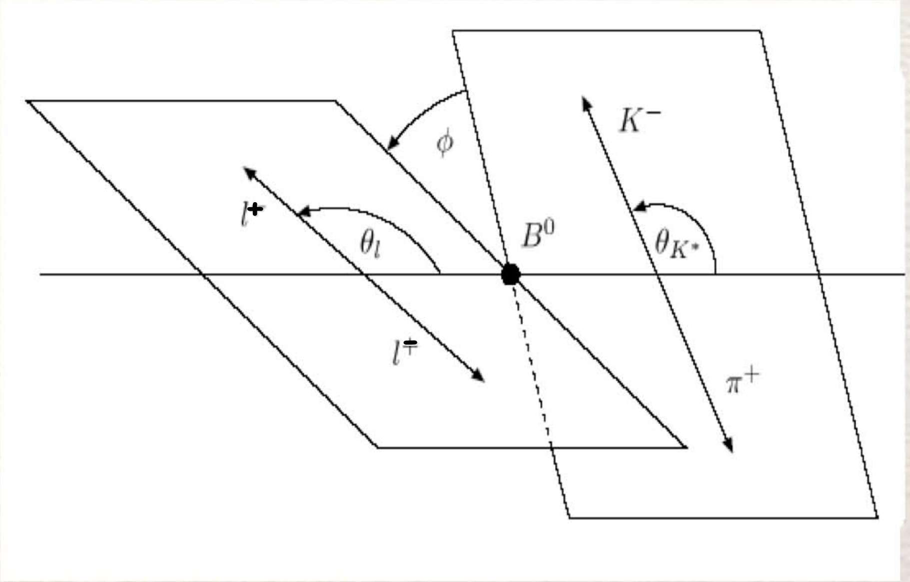
➔ expect ~4500 events in 75 ab^{-1} SuperB sample ~1900 for q^2<6 GeV^2

- With method we can also study $B\to X_s\tau^+\tau^-$

Angular Distributions in $B \to K^* \ell^+ \ell^-$

- The $B \to K^* \ell^+ \ell^-$ angular distribution depends on three angles, θ_K, θ_ℓ, ϕ

- The one-dimensional projections allow to extract the longitudinal polarization and the lepton forward backward asymmetry for different q^2 regions



$$W(\cos\theta_K) = \tfrac{3}{2}\mathcal{F}_L \cos^2\theta_K + \tfrac{3}{4}(1-\mathcal{F}_L)\sin^2\theta_K$$

$$W(\cos\theta_\ell) = \tfrac{3}{4}\mathcal{F}_L \sin^2\theta_\ell + \tfrac{3}{8}(1-\mathcal{F}_L)(1+\cos^2\theta_\ell) + \mathcal{A}_{FB}\cos\theta_\ell$$

- In BABAR, we measure $\mathcal{F}_L$ and $\mathcal{A}_{FB}$ in two bins of q^2

- In SuperB at 75 ab^{-1} the full angular distribution can be explored for different q^2 bins

- With high statistic we can explore $\mathcal{A}_{FB}$ of $B \to K \ell^+ \ell^-$ to limit right-handed currents

Angular Distributions in $B \to X_s \ell^+ \ell^-$

- The $B \to X_s \ell^+ \ell^-$ angular distribution depends on θ_ℓ

$$W(\cos\theta_\ell) = \frac{3}{8}\left[\left(1+\cos^2\theta_\ell\right)H_T(q^2) + 2\cos\theta_\ell H_A(q^2) + 2\left(1-\cos^2\theta_\ell\right)H_L(q^2)\right]$$

- H_L, H_T, H_A are 3 independent (q^2 dep) functions of Wilson coefficients

$$H_A(q^2) \sim \mathcal{A}_{FB}(q^2)$$

- All three functions can be measured with high precision at 75 fb^{-1} in 12 (6) bins of q^2 below $q^2<6$ GeV^2

- For $B \to X_s \ell^+ \ell^-$ (exclusive sum) expect statistical uncertainty of ~0.033 per bin (12 bins) systematic error expected around 0.04-0.06

- For $B \to X_s \ell^+ \ell^-$ (exclusive sum) expect statistical uncertainty of ~0.10 per bin (6 bins), systematic error is expected to be 0.04-0.06

Angular Distributions for $B \to [X_s, K^{(*)}]\ell^+\ell^-$

- $\mathcal{A}_{FB}$ results from interplay between $C_9(s)C_{10}$ and $C_7 C_{10}/s$

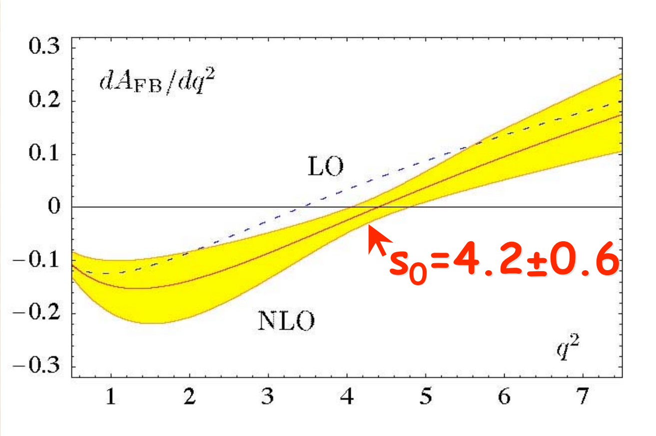
$$\frac{d\mathcal{A}_{FB}}{ds} \propto -\left\{ \mathrm{Re}\left[C_9^{eff}(s)C_{10}\right] VA_1 + \frac{m_b m_B}{s} \mathrm{Re}\left[C_7^{eff} C_{10}\right]\left[VT_2 \left(1 - \frac{m_{K^*}}{m_B}\right) + A_1 T_1 \left(1 + \frac{m_{K^*}}{m_B}\right)\right]\right\} \quad K^* \ell^+\ell^-$$

form factors

- Recent SM calculations focus on low s-region

$K^* \ell^+\ell^-$

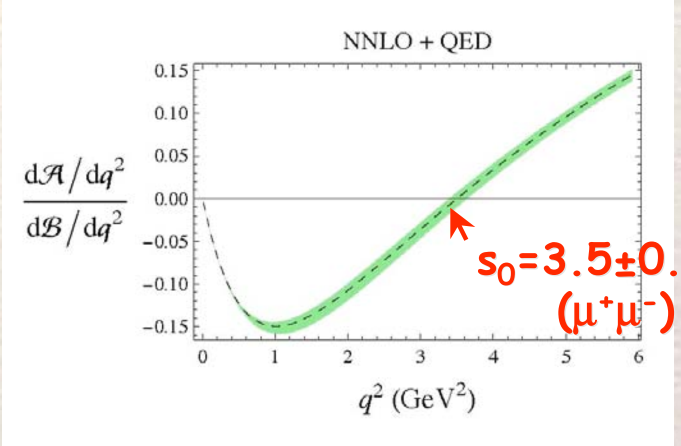
$\mathcal{O}(\alpha_s)$



Feldmann & Matias JHEP 0301, 074 (2003)

$X_s \ell^+\ell^-$

$\mathcal{O}(\alpha_s^2)$

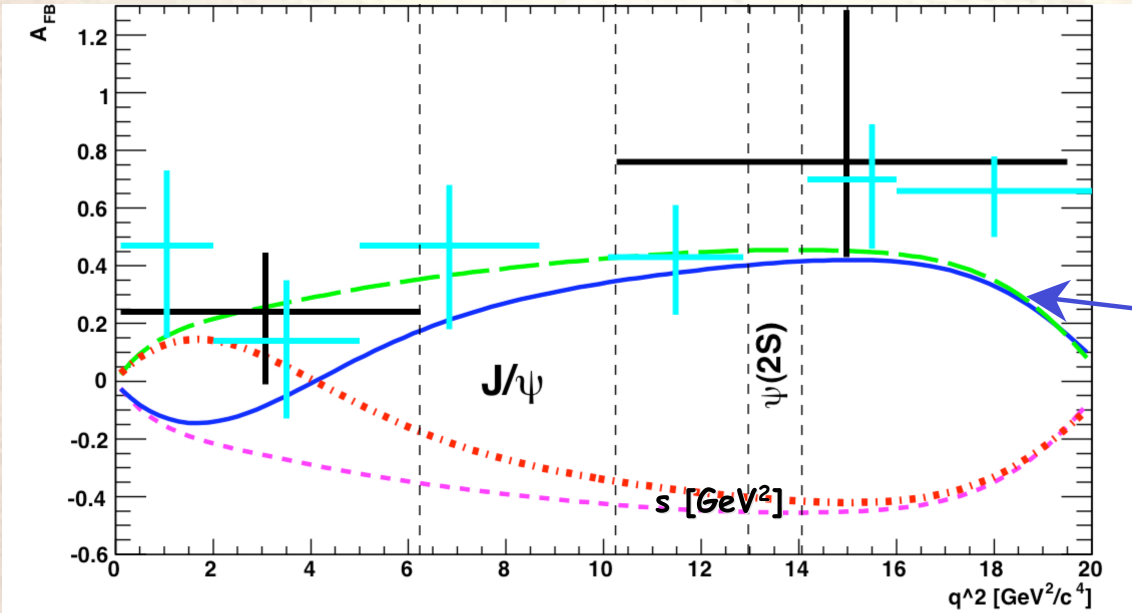


Huber, Hurth & Lunghi hep-ph/0712.3009

- In the SM, $\mathcal{A}_{FB}$ crosses zero around s_0 =3.5-4.5 GeV^2

Lepton Forward-Backward Asymmetry $\mathcal{A}_{FB}$

- BABAR (349 fb^{-1}) and Belle (605 fb^{-1}) $\mathcal{A}_{FB}$ measurements



$0.1 \le q^2 \le 6.25$ GeV^2

$\mathcal{A}_{FB}^{low\ q^2} = 0.24^{+0.18}_{-0.23} \pm 0.06$

SM

$\mathcal{A}_{FB} = -\mathcal{A}_{FB}^{SM}$

$C_9 C_{10} = -C_9 C_{10}^{SM}$

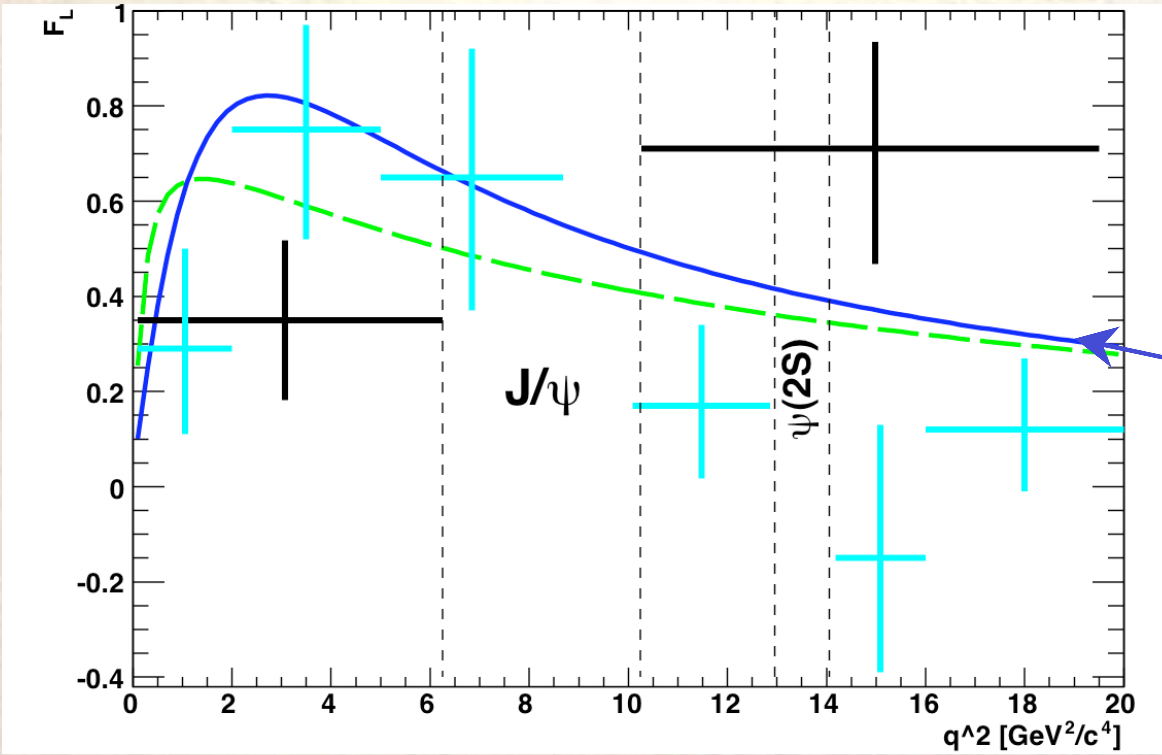
$C_7 = -C_7^{SM}$

- For $B \to K^* \ell^+ \ell^-$ expect statistical uncertainty of 0.05-0.06 per bin (12 bins), systematic error may be reducible to 0.05-0.06

- Look at $\mathcal{A}_{FB}$ of $B \to K^{*0} \ell^+ \ell^-$ and $B \to K^{*+} \ell^+ \ell^-$ separately

K* longitudinal Polarization $\mathcal{F}_L$

- BABAR (349 fb^{-1}) and Belle (605 fb^{-1}) $\mathcal{A}_{FB}$ measurements



$0.1 \le q^2 \le 6.25$ GeV^2

$\mathcal{F}_L^{\text{low } q^2} = 0.35 \pm 0.16 \pm 0.04$

SM

– – $C_7 = -C_7^{SM}$

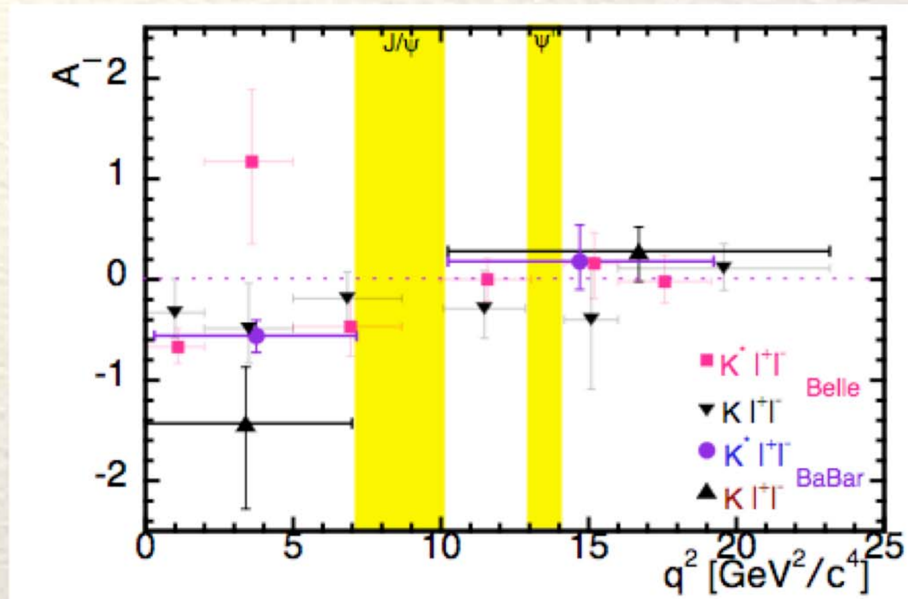
- For $B \to K^* \ell^+ \ell^-$ expect statistical uncertainty of 0.04-0.05in each of 12 bins (q^2<6 GeV^2)
  ➔ systematic error may be reducible to 0.04-0.05

Isospin Asymmetry

- Define isospin asymmetry in different q^2 bins:

$$\mathcal{A}_I^{s-\mathrm{bin}} \equiv \frac{\mathcal{B}^{q^2-\mathrm{bin}}(B^0 \to X_s^0 \ell^+\ell^-) - r_\tau \mathcal{B}^{q^2-\mathrm{bin}}(B^\pm \to X_s^\pm \ell^+\ell^-)}{\mathcal{B}^{q^2-\mathrm{bin}}(B^0 \to X_s^0 \ell^+\ell^-) + r_\tau \mathcal{B}^{q^2-\mathrm{bin}}(B^\pm \to \bar{X}_s^\pm \ell^+\ell^-)}$$

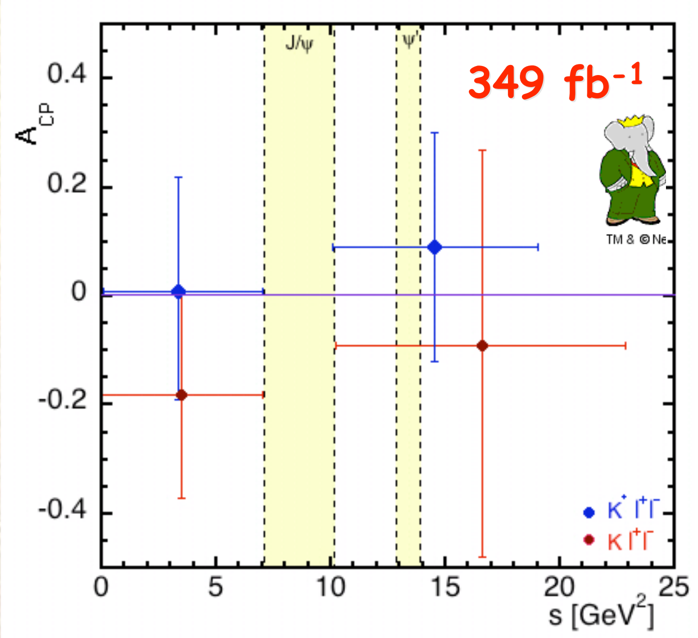
- Scale B^+ branching fractions by $r_\tau = \tau_{B0}/\tau_{B+} = 1/(1.071 \pm 0.009)$
- BABAR measures significant $\mathcal{A}_I$ in low q^2 region ➔ $K\ell^+\ell^-$ and $K^*\ell^+\ell^-$ combined modes differ from Standard Model by 3.9σ
- Belle results agree with BABAR results



- For 75 ab^{-1} in SuperB, we can measure $\mathcal{A}_I$ in $B \to K^{(*)}\ell^+\ell^-$ and $B \to X_s \ell^+\ell^-$ (sum of exclusive modes) in at least 12 bins or $B \to X_s \ell^+\ell^-$ (recoil method) in at least 6 bins for $q^2 < 6$ GeV^2 ➔map out q^2 dependence

CP Asymmetry

- Define $$\mathcal{A}_{CP} \equiv \frac{\mathcal{B}(\bar{B}\to \bar{X}_s \ell^+\ell^-) - \mathcal{B}(B\to X_s \ell^+\ell^-)}{\mathcal{B}(\bar{B}\to \bar{X}_s \ell^+\ell^-) + \mathcal{B}(B\to X_s \ell^+\ell^-)}$$
- In SM $\mathcal{A}_{CP}$ is ~1%
- For 75 ab^{-1} in SuperB, expected precision of $\mathcal{A}_{CP}(B\to K^{(*)}\ell^+\ell^-)$ is ~0.011 (0.010)
- For 75 ab^{-1} in SuperB, we can compare $\mathcal{A}_{CP}(B\to X_s\ell^+\ell^-)$ from recoil method with $\mathcal{A}_{CP}(B\to X_s\ell^+\ell^-)$ from sum of exclusive since $\mathcal{A}_{CP}(B\to X_d\ell^+\ell^-)$ may be ~20% in SM



$$\mathcal{A}_{CP}^{\text{all } q^2}(B^\pm \to K^\pm \ell^+\ell^-) = -0.18^{+0.18}_{-0.18}$$

$$\mathcal{A}_{CP}^{\text{all } q^2}(B \to K^* \ell^+\ell^-) = -0.02^{+0.16}_{-0.16}$$

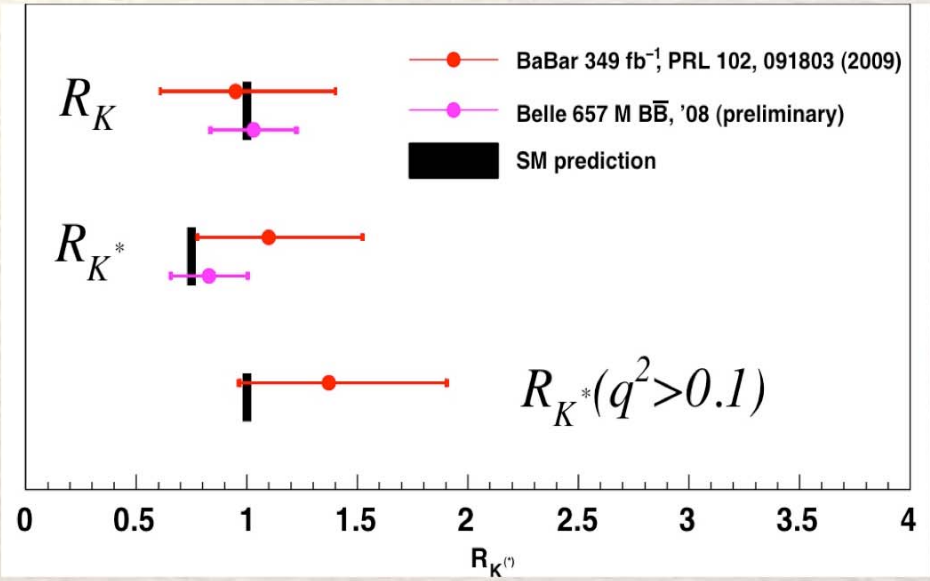
- Precision for sum of exclusive is <0.008 and for recoil method is ~0.027
- Systematic error is <0.01

Lepton Flavor Asymmetries

- Define ratios $\mathcal{R}_K \equiv \frac{\mathcal{B}(B \to K e^+ e^-)}{\mathcal{B}(B \to K \mu^+ \mu^-)}$ $\mathcal{R}_{K^*} \equiv \frac{\mathcal{B}(B \to K^* e^+ e^-)}{\mathcal{B}(B \to K^* \mu^+ \mu^-)}$ $\mathcal{R}_{X_s} \equiv \frac{\mathcal{B}(B \to X_s e^+ e^-)}{\mathcal{B}(B \to X_s \mu^+ \mu^-)}$
- In the SM $\mathcal{R}_{K,K^*,Xs}$ =1 (for pole region removed q^2 >0.1 GeV^2)
- BABAR measures values consistent with one as Belle

$$\mathcal{R}_K^{\text{all } q^2} = 0.96^{+0.44}_{-0.34} \pm 0.05$$

$$\mathcal{R}_{K^*}^{\text{all } q^2} = 1.37^{+0.53}_{-0.40} \pm 0.09$$



- For 75 ab^{-1} in SuperB, we expect statistical errors of ~0.02-0.03 for $R_{K(*)}$, systematic error may be reduced to 0.04(0.06)
- For 75 ab^{-1} in inclusive modes (SEM) expect accuracy of ~1.6% (5.6%), systematic error is ~5% (5%)

Summary of Expectations for 75 ab^{-1}

- Expected uncertainties in $K\ell^+\ell^-$, $K^*\ell^+\ell^-$, $K^{*0}\ell^+\ell^-$ in LHCb, $X_s\ell^+\ell^-$ in sum of exclusive modes and $X_s\,\ell^+\ell^-$ in the recoil method

mode	$\Delta\mathcal{B}/\mathcal{B}$ tot [%]	$\Delta\mathcal{B}/\mathcal{B}$ low [%]	$\mathcal{R}_{Xs}$ tot [%]	$\mathcal{F}_L/H_L$ low	$\mathcal{A}_{FB}$ low	$\mathcal{A}_{CP}$ tot	$\mathcal{A}_I$ low
K σ_{stat}	1.1	4.4/bin	2.4	-	-	0.011	0.08/bin
σ_{sys}	3-4	3-4	3	-	-	0.008	0.03
K* σ_{stat}	1.1	5.2/bin	2.0	.034/bin	.043/bin	0.01	0.03/bin
σ_{sys}	4-5	4-5	4	.027-.03	.033-.04	0.008	0.03
K^{*0} LHCb σ_{stat}	0.7				0.05/bin		
σ_{sys}	?	?					
X_s (SEM) σ_{stat}	0.7	3.3/bin	1.2	.021/bin	.027/bin	0.006	0.020/bin
σ_{sys}	5-6	5-6	5	0.04-.05	0.05-.06	0.01-0.02	0.03-.04
X_s (RM) σ_{stat}	2.2	7.8/bin	4.1	.051/bin	.065/bin	0.02	0.049/bin
σ_{sys}	5-6	5-6	5	0.04-.05	0.05-.06	0.01-0.02	0.03-.04

- For SuperB assume 75 ab^{-1}, for LHCb 5 years at 2fb^{-1}, low (q^2<6 GeV^2) 12 bins (exclusive & sum of exclusive modes), 6 bins for recoil method and LHCb

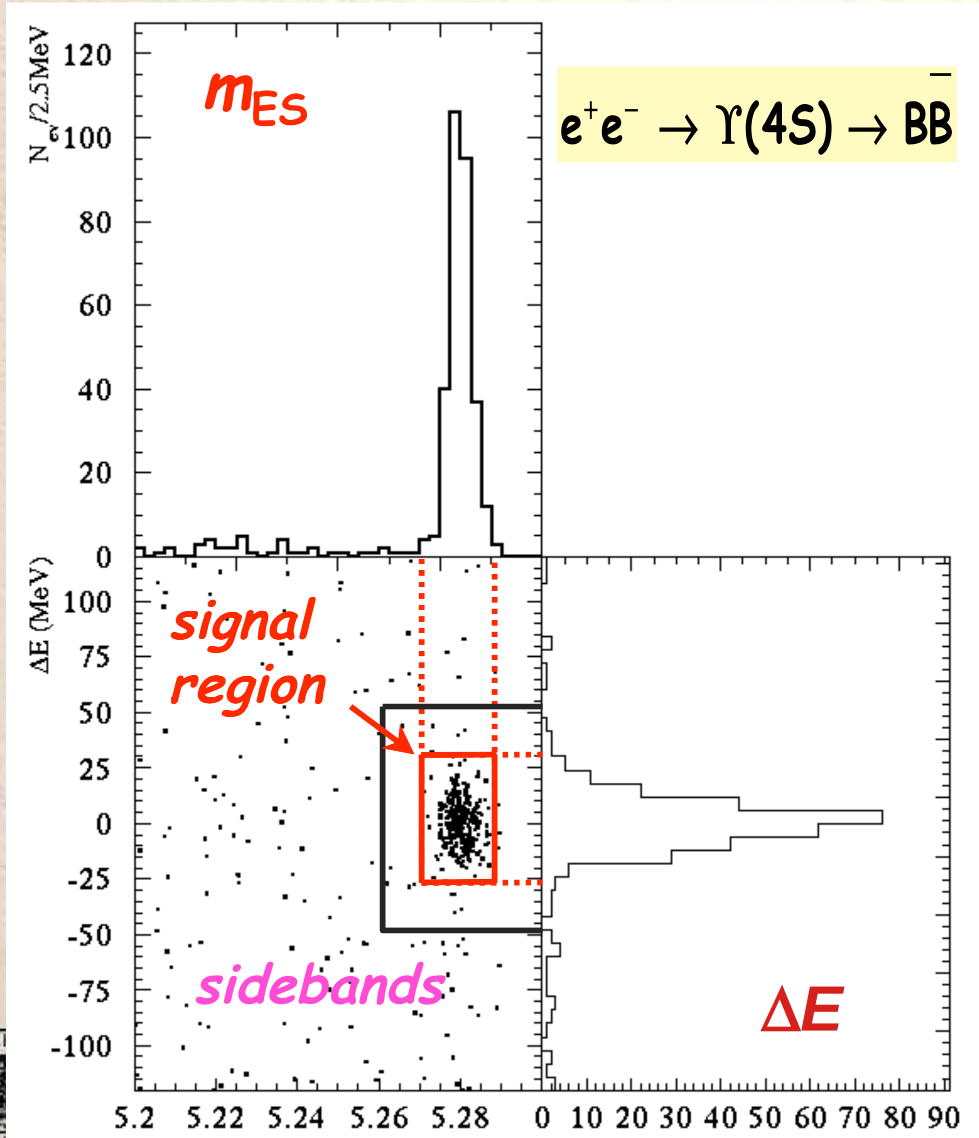
Conclusion

- At SuperB exclusive and inclusive $B\to X_s \ell^+\ell^-$ modes will be measured with high precision, at 75 ab^{-1} statistical precision is few% measurements already will be systematics limited
- With this high statistics there is a great potential to explore other observables, e.g. amplitudes in full angular analysis
- With 12 bins below q^2<6 GeV^2 the zero crossing of $\mathcal{A}_{FB}$ if existent in $B\to X_s \ell^+\ell^-$ and $B\to X_s \ell^+\ell^-$ will be determined rather precisely to better than $\sigma(q^2_0)$=0.5 GeV^2 (precision claimed by LHCb in 1 year)
- Using recoil method at SuperB allows for unbiased $B\to X_s \ell^+\ell^-$ measurement, extract $B\to X_d \ell^+\ell^-$ to extract $|V_{td}/V_{ts}|$, measure $B\to X\tau\tau$
- Sum of exclusive modes provides useful cross check for recoil method
- There will be a lot of pressure to reduce systematic error by >> 30%
- Thus, there is a great potential to see new physics at <$\mathcal{O}$(0.1)

Backup Slides

Exclusive $B \to K^{(*)} \ell^+ \ell^-$

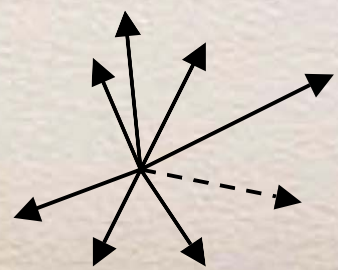
- In center-of-mass frame B-mesons are ~at rest
  ➔ useful kinematic constraints



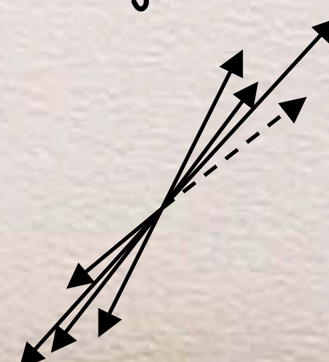
- $m_{ES} = \sqrt{E^{*2}_{beam} - \vec{p}^{\,*2}_B}$
- $\Delta E = E^*_B - E^*_{Beam}$
- m_{X_s}

- Event shapes

$\Upsilon(4S) \to B\bar{B}$
spherical

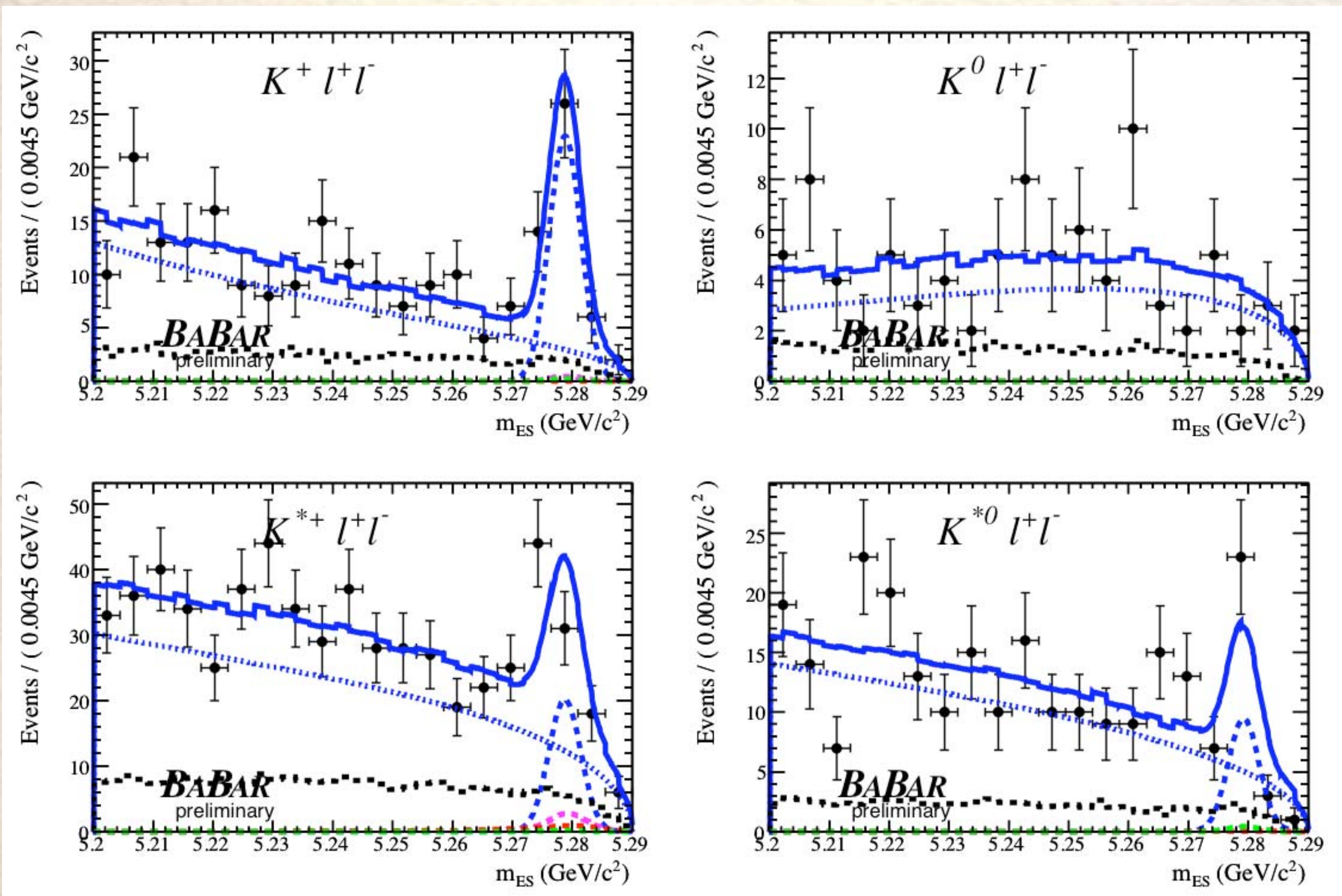


$e^+e^- \to q\bar{q}$
jetlike



m_{ES} Distributions in the Low q^2-Bin

- For exclusive analyses achieve good signal/background ratios



signal

combinatorial background

fake muons

self cross feed bkg

feed across background

other peaking backgrounds

Sum of Exclusive $B \to X_s \ell^+\ell^-$ Decays

- Efficiency for $B \to X_s e^+e^-$ modes

X_s topo.	gen.	skim + in lists	presel.	+ − sel.	best B cand.	postsel.	J/ , veto	LR cut	Total e .
K	29.8	14.6	12.4	12.0	11.3	10.4	6.4	5.00	16.8%
		(49.0%)	(84.8%)	(96.6%)	(94.4%)	(91.6%)	(62.1%)	(77.8%)	
$K\pi^0$	49.2	7.2	6.1	5.7	4.3	3.9	2.80	1.64	3.3%
		(13.9%)	(84.3%)	(94.5%)	(74.4%)	(90.7%)	(72.3%)	(58.7%)	
$K\pi$	96.5	33.1	26.6	25.4	20.4	18.6	11.6	6.9	7.1%
		(33.7%)	(80.4%)	(95.5%)	(80.1%)	(91.5%)	(62.2%)	(59.2%)	
$K\pi\pi^0$	65.1	5.8	4.8	4.3	2.63	2.13	1.82	0.72	1.1%
		(9.0%)	(82.2%)	(90.6%)	(60.8%)	(81.2%)	(85.4%)	(39.3%)	
$K\pi\pi$	53.8	13.4	9.8	9.0	6.4	5.2	4.3	2.00	3.7%
		(24.1%)	(73.3%)	(92.3%)	(71.0%)	(81.2%)	(82.9%)	(46.3%)	
K^0_S	14.9	4.4	3.8	3.7	3.6	3.4	2.25	1.59	10.7%
		(29.5%)	(87.0%)	(96.9%)	(97.5%)	(93.6%)	(66.6%)	(70.4%)	
$K^0_S\pi^0$	26.6	2.32	2.01	1.92	1.24	1.13	0.83	0.54	2.0%
		(8.7%)	(86.8%)	(95.4%)	(64.7%)	(91.5%)	(73.4%)	(65.0%)	
$K^0_S\pi$	47.8	8.3	6.9	6.6	5.2	4.8	3.1	1.77	3.7%
		(17.6%)	(83.1%)	(95.4%)	(79.1%)	(91.7%)	(64.5%)	(57.3%)	
$K^0_S\pi\pi^0$	32.2	1.54	1.29	1.14	0.69	0.56	0.43	0.19	0.6%
		(4.8%)	(84.0%)	(88.2%)	(60.7%)	(80.5%)	(76.8%)	(43.7%)	
$K^0_S\pi\pi$	27.2	3.5	2.73	2.39	1.65	1.33	1.15	0.39	1.4%
		(12.9%)	(77.8%)	(87.7%)	(68.9%)	(80.8%)	(86.6%)	(33.5%)	
Total	443.0	94.2	76.4	72.2	57.4	51.4	34.7	20.7	4.67%
		(21.6%)	(81.1%)	(94.6%)	(79.4%)	(89.5%)	(67.5%)	(59.6%)	

Sum of Exclusive $B \to X_s \ell^+ \ell^-$ Decays

- Efficiency for $B \to X_s \mu^+ \mu^-$ modes

X_s topo.	gen.	skim + in lists	presel.	$^+$ $^-$ sel.	best B cand.	postsel.	J/ , veto	LR cut	Total e .
K	29.9	5.5 (18.0%)	5.1 (92.8%)	4.6 (90.1%)	4.4 (96.5%)	4.1 (93.0%)	3.1 (75.5%)	2.66 (86.1%)	8.9%
$K\pi^0$	44.9	1.90 (4.3%)	1.73 (91.0%)	1.42 (82.4%)	1.23 (86.4%)	1.16 (94.8%)	0.87 (74.7%)	0.47 (54.4%)	1.05%
$K\pi$	85.0	10.1 (12.0%)	8.9 (87.5%)	7.9 (89.5%)	6.5 (82.2%)	6.0 (92.0%)	4.3 (70.9%)	2.77 (65.3%)	3.3%
$K\pi\pi^0$	44.7	1.28 (2.8%)	1.14 (89.5%)	0.90 (78.9%)	0.59 (65.2%)	0.53 (91.0%)	0.41 (75.9%)	0.16 (40.5%)	0.37%
$K\pi\pi$	37.7	2.65 (6.9%)	2.18 (82.3%)	1.74 (79.8%)	1.40 (80.7%)	1.11 (78.8%)	0.89 (80.2%)	0.46 (52.0%)	1.22%
K_S^0	15.0	1.40 (9.3%)	1.38 (98.6%)	1.26 (91.1%)	1.24 (98.4%)	1.14 (91.9%)	0.79 (69.7%)	0.65 (81.6%)	4.3%
$K_S^0\pi^0$	22.3	0.55 (2.5%)	0.54 (97.7%)	0.40 (74.2%)	0.31 (79.1%)	0.31 (97.0%)	0.20 (64.5%)	0.08 (38.4%)	0.34%
$K_S^0\pi$	40.5	2.49 (6.2%)	2.26 (90.9%)	1.84 (81.4%)	1.55 (84.1%)	1.45 (93.7%)	1.09 (75.4%)	0.61 (55.7%)	1.50%
$K_S^0\pi\pi^0$	21.9	0.37 (1.6%)	0.34 (93.9%)	0.28 (81.8%)	0.17 (61.9%)	0.17 (95.4%)	0.12 (71.7%)	0.05 (42.8%)	0.23%
$K_S^0\pi\pi$	19.2	0.69 (3.6%)	0.59 (86.3%)	0.45 (75.6%)	0.32 (72.5%)	0.27 (83.9%)	0.21 (78.7%)	0.09 (43.6%)	0.48%
Total	361.1	26.9 (7.5%)	24.1 (89.6%)	20.8 (86.3%)	17.7 (85.4%)	16.2 (91.5%)	11.9 (73.5%)	8.0 (67.2%)	2.22%

Exclusive $B \to K^{(*)} \ell^+ \ell^-$

- Breakdown of systematic uncertainties in decay rates

Mode	$K_S^0\mu^+\mu^-$	$K^\pm\mu^+\mu^-$	$K_S^0e^+e^-$	$K^\pm e^+e^-$	$K^{*\pm}\mu^+\mu^-$	$K^{*0}\mu^+\mu^-$	$K^{*\pm}e^+e^-$	$K^{*0}e^+e^-$
LepTrkCorr	±1.6	±1.6	±1.6	±1.6	±1.6	±1.6	±1.6	±1.6
HadTrkCorr	±2.8	±1.4	±2.8	±1.4	±3.4	±2.8	±3.0	±2.8
BBCount	±1.1	±1.1	±1.1	±1.1	±1.1	±1.1	±1.1	±1.1
ElecIDCorr	—	—	±0.7	±0.7	—	—	±0.7	±0.7
MuonIDCorr	±1.0	±1.0	—	—	±1.0	±1.0	—	—
KaonIDCorr	—	±0.6	—	±0.6	±0.2	±0.6	±0.3	±0.6
PionIDCorr	—	—	—	—	±0.1	±0.2	±0.1	±0.1
KsDistCorr	±0.9	—	±0.9	—	±0.6	—	±0.5	—
NNEffCorr	±0.0	±2.0	±1.6	±1.6	±2.0	±0.8	±2.0	±0.8
KinemCorr	±1.9	±1.1	±2.9	±2.8	±2.5	±5.0	±1.6	±3.4
MCStatEff	±0.4	±0.4	±0.4	±0.3	±0.6	±0.5	±0.7	±0.5
Pi0EffCorr	—	—	—	—	±0.9	—	±1.3	—
GaussMean	±0.6	±0.2	±9.8	±0.2	±1.5	±0.5	±0.6	±0.3
GaussWidth	±2.1	±0.6	±11.0	±0.2	±2.4	±0.2	±0.8	±0.3
HadShape	±4.2	±3.1	—	—	±4.5	±2.3	—	—
NonHadPeaks	±0.6	±2.3	±5.1	±0.8	±0.8	±0.9	±0.4	±0.4
Total Syst.	±7.0	±5.7	±16.6	±4.7	±8.2	±7.4	±5.8	±5.8

Exclusive $B \to K^{(*)} \ell^+ \ell^-$

- Breakdown of systematic uncertainties in angular analysis

TABLE IV: Systematic errors on the measurements of F_L and A_{FB} in the $K\ \ ^{+}\ ^{-}$ samples.

Source of Error	F_L low q^2	F_L high q^2	A_{FB} low q^2	A_{FB} high q^2
m_{ES} fit yields	0.001	0.016	0.003	0.002
F_L fit error			0.025	0.022
Background shape	0.011	0.008	0.017	0.021
Signal model	0.036	0.034	0.030	0.038
Fit bias	0.012	0.020	0.023	0.052
Mis-reconstructed signal	0.010	0.010	0.020	0.020
Total	0.041	0.044	0.052	0.074

Summary of Expectations for 1 ab^{-1}

- Expected uncertainties in $K\ell^+\ell^-$, $K^*\ell^+\ell^-$, $K^{*0}\ell^+\ell^-$ in LHCb, $X_s\ell^+\ell^-$ in sum of exclusive modes and $X_s\ell^+\ell^-$ in the recoil method

mode	$\Delta\mathcal{B}/\mathcal{B}$ tot [%]	$\Delta\mathcal{B}/\mathcal{B}$ low [%]	$\mathcal{R}_{Xs}$ tot [%]	$\mathcal{F}_L/H_L$ low	$\mathcal{A}_{FB}$ low	$\mathcal{A}_{CP}$ tot	$\mathcal{A}_I$ low
K σ_{stat}	9.0	17.4/bin	19	-	-	0.09	0.32/bin
σ_{sys}	3-4	3-4	4	-	-	0.008	0.03
K^* σ_{stat}	8.4	20.7/bin	16.1	.136/bin	.171/bin	0.077	0.129/bin
σ_{sys}	4-5	4-5	5	.027-.03	.033-.04	0.008	0.03
X_s (SEM) σ_{stat}	5.2	12.9/bin	9.7	.084/bin	.107/bin	0.045	0.081/bin
σ_{sys}	5-6	5-6	5	0.04-.05	0.05-.06	0.01-0.02	0.03-.04
X_s (RM) σ_{stat}	17.4	30.7/bin	32.3	.2/bin	.26/bin	0.15	0.19/bin
σ_{sys}	5-6	5-6	5	0.04-.05	0.05-.06	0.01-0.02	0.03-.04

- For SuperB assume 1 ab^{-1}, low (q^2<6 GeV^2) 3 bins (exclusive & sum of exclusive modes)

Summary of Expectations for 5 ab^{-1}

- Expected uncertainties in $K\ell^+\ell^-$, $K^*\ell^+\ell^-$, $K^{*0}\ell^+\ell^-$ in LHCb, $X_s\ell^+\ell^-$ in sum of exclusive modes and $X_s\,\ell^+\ell^-$ in the recoil method

mode	$\Delta\mathcal{B}/\mathcal{B}$ tot [%]	$\Delta\mathcal{B}/\mathcal{B}$ low [%]	$\mathcal{R}_{Xs}$ tot [%]	$\mathcal{F}_L/H_L$ low	$\mathcal{A}_{FB}$ low	$\mathcal{A}_{CP}$ tot	$\mathcal{A}_I$ low
K σ_{stat}	4.4	17/bin	9.5	-	-	0.044	0.32/bin
σ_{sys}	3-4	3-4	4	-	-	0.008	0.03
K* σ_{stat}	4.1	20/bin	7.9	.13/bin	.17/bin	0.038	0.13/bin
σ_{sys}	4-5	4-5	5	.027-.03	.033-.04	0.008	0.03
X_s (SEM) σ_{stat}	2.5	12.6/bin	4.7	.082/bin	.1/bin	0.022	0.079/bin
σ_{sys}	5-6	5-6	5	0.04-.05	0.05-.06	0.01-0.02	0.03-.04
X_s (RM) σ_{stat}	8.5	30/bin	15.8	.2/bin	.25/bin	0.076	0.19/bin
σ_{sys}	5-6	5-6	5	0.04-.05	0.05-.06	0.01-0.02	0.03-.04

- For SuperB assume 5 ab^{-1}, low (q^2<6 GeV^2) 12 bins (exclusive & sum of exclusive modes), 6 bins for recoil method

Summary of Expectations for 15 ab^{-1}

- Expected uncertainties in $K\ell^+\ell^-$, $K^*\ell^+\ell^-$, $K^{*0}\ell^+\ell^-$ in LHCb, $X_s\ell^+\ell^-$ in sum of exclusive modes and $X_s\ell^+\ell^-$ in the recoil method

mode	$\Delta\mathcal{B}/\mathcal{B}$ tot [%]	$\Delta\mathcal{B}/\mathcal{B}$ low [%]	$\mathcal{R}_{Xs}$ tot [%]	$\mathcal{F}_L/H_L$ low	$\mathcal{A}_{FB}$ low	$\mathcal{A}_{CP}$ tot	$\mathcal{A}_I$ low
K σ_{stat}	2.6	9.9/bin	5.5	-	-	0.026	0.18/bin
σ_{sys}	3-4	3-4	4	-	-	0.008	0.03
K^* σ_{stat}	2.4	11.7/bin	4.6	.077/bin	.097/bin	0.022	0.073/bin
σ_{sys}	4-5	4-5	5	.027-.03	.033-.04	0.008	0.03
X_s (SEM) σ_{stat}	1.5	7.3/bin	2.7	.047/bin	.055/bin	0.013	0.046/bin
σ_{sys}	5-6	5-6	5	0.04-.05	0.05-.06	0.01-0.02	0.03-.04
X_s (RM) σ_{stat}	4.9	17.3/bin	9.1	0.11/bin	.15/bin	0.044	0.11/bin
σ_{sys}	5-6	5-6	5	0.04-.05	0.05-.06	0.01-0.02	0.03-.04

- For SuperB assume 15 ab^{-1}, low ($q^2<6$ GeV^2) 12 bins (exclusive & sum of exclusive modes), 6 bins for recoil method

Summary of Expectations for 50 ab^{-1}

- Expected uncertainties in $K\ell^+\ell^-$, $K^*\ell^+\ell^-$, $K^{*0}\ell^+\ell^-$ in LHCb, $X_s\ell^+\ell^-$ in sum of exclusive modes and $X_s\,\ell^+\ell^-$ in the recoil method

mode	$\Delta\mathcal{B}/\mathcal{B}$ tot [%]	$\Delta\mathcal{B}/\mathcal{B}$ low [%]	$\mathcal{R}_{Xs}$ tot [%]	$\mathcal{F}_L/H_L$ low	$\mathcal{A}_{FB}$ low	$\mathcal{A}_{CP}$ tot	$\mathcal{A}_I$ low
K σ_{stat}	1.4	5.4/bin	3	-	-	0.014	0.1/bin
σ_{sys}	3-4	3-4	3	-	-	0.008	0.03
K^* σ_{stat}	1.3	6.4/bin	2.5	.042/bin	.053/bin	0.012	0.04/bin
σ_{sys}	4-5	4-5	4	.027-.03	.033-.04	0.008	0.03
K^{*0} LHCb σ_{stat}	0.7				0.05/bin		
σ_{sys}	?	?					
X_s (SEM) σ_{stat}	0.8	4/bin	1.5	.026/bin	.033/bin	0.007	0.025/bin
σ_{sys}	5-6	5-6	5	0.04-.05	0.05-.06	0.01-0.02	0.03-.04
X_s (RM) σ_{stat}	2.7	9.5/bin	5	.062/bin	.08/bin	0.024	0.06/bin
σ_{sys}	5-6	5-6	6	0.04-.05	0.05-.06	0.01-0.02	0.03-.04

- For SuperB assume 50 ab^{-1}, for LHCb 5 years at 2fb^{-1}, low (q^2<6 GeV^2) 12 bins (exclusive & sum of exclusive modes), 6 bins for recoil method and LHCb