Exclusive $B \to K^* ll$

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SuperB,Elba 31-05-2011

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

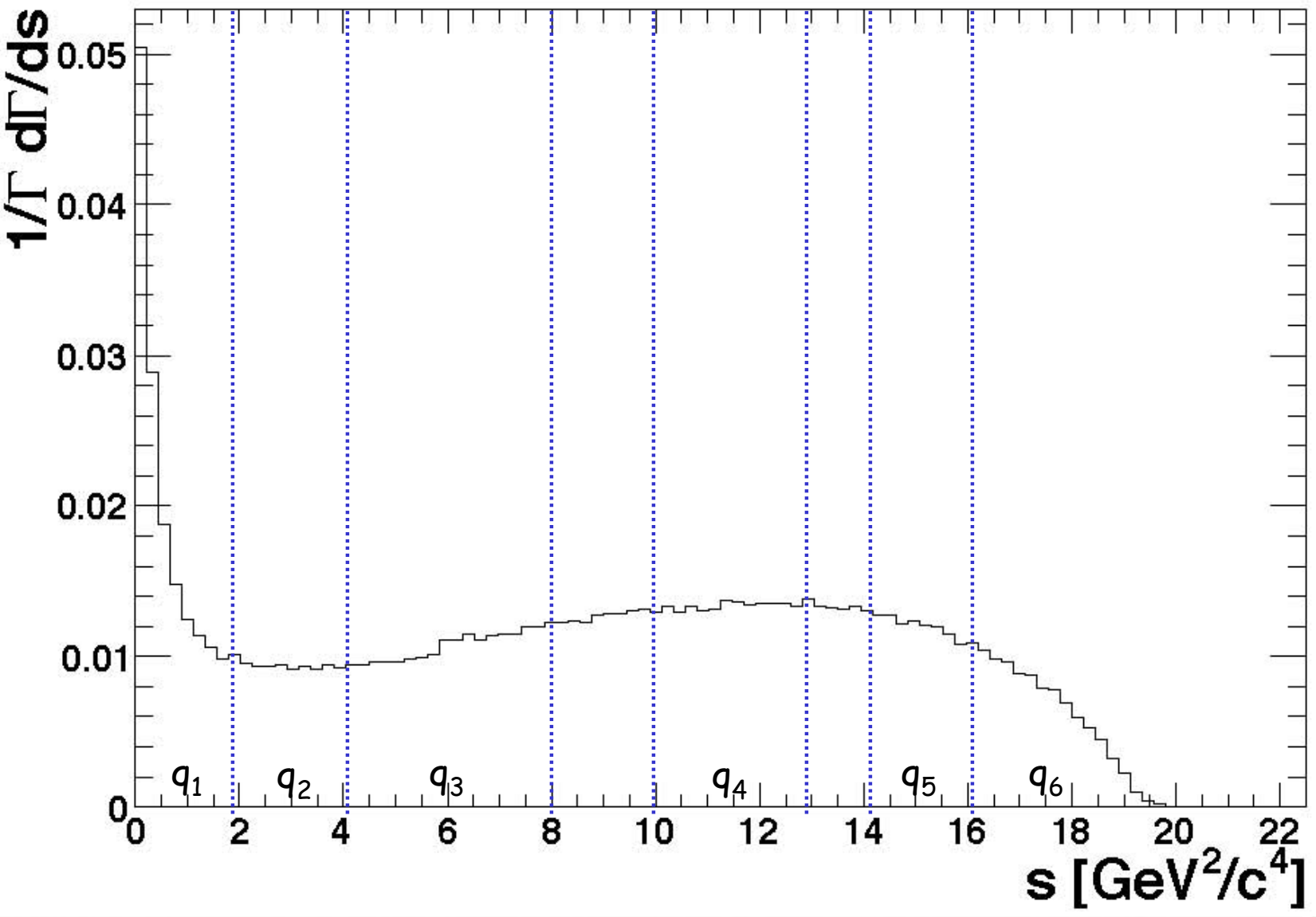
- BABAR reconstructs $B \to K^* \ell^+\ell^-$ in 10 exclusive final states, K^+, K^0_S, $K^+\pi^-$, $K^+\pi^0$, $K^0_S\pi^+$ recoiling against e^+e^- or $\mu^+\mu^-$
- The data have been plotted in 2 bins of q^2
  low q^2: $0.1 \leq q^2 \leq 7.02$ (6.25) GeV^2, reduced q^2 for angular analysis
  high q^2: $10.24 \leq q^2 \leq 12.96$ 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 $B \to \psi(2S)K^{(*)}$

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

- At SuperB we will use the same modes
- I will use BABAR data for extrapolation, since the SuperB detector is based on the BABAR detector and we understand both statistical and systematic errors

Exclusive $B \to K^* \ell^+ \ell^-$ Decay Rate



Event Statistics in 6 q^2 Bins

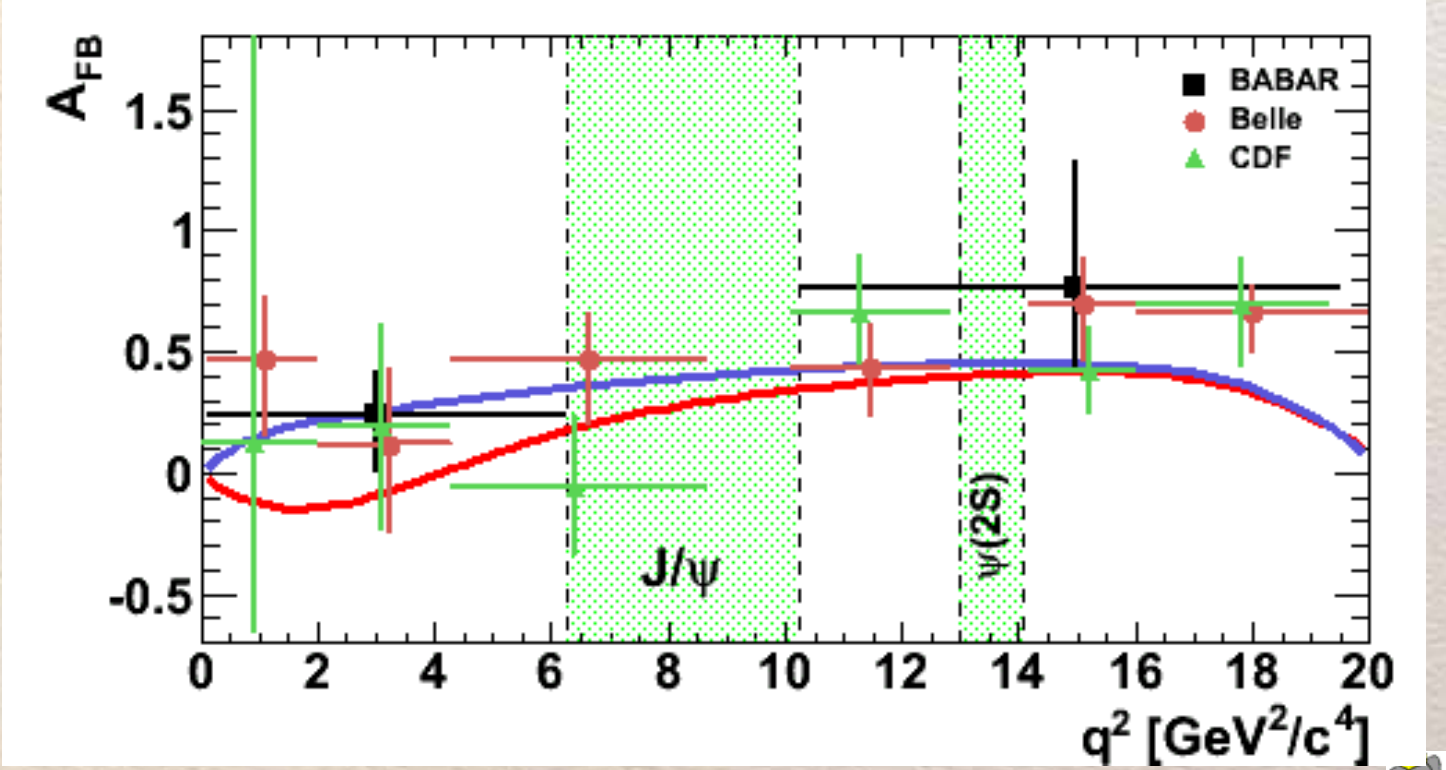
- Number of events in BABAR for 425 fb^{-1} and extrapolations to 75 ab^{-1}

- Number of events measured in q_{low} and q_{high} are redistributed to the 6 q^2 bins

	BABAR	SuperB
q_{low}	42.9	**7571**
q_{high}	53.7	**9476**
q_1	11.8	2077
q_2	9.5	1678
q_3	21.6	3815
q_4	25.2	4444
q_5	15.2	2676
q_6	13.4	2357

A_{FB} in $B \to K^* \ell^+ \ell^-$

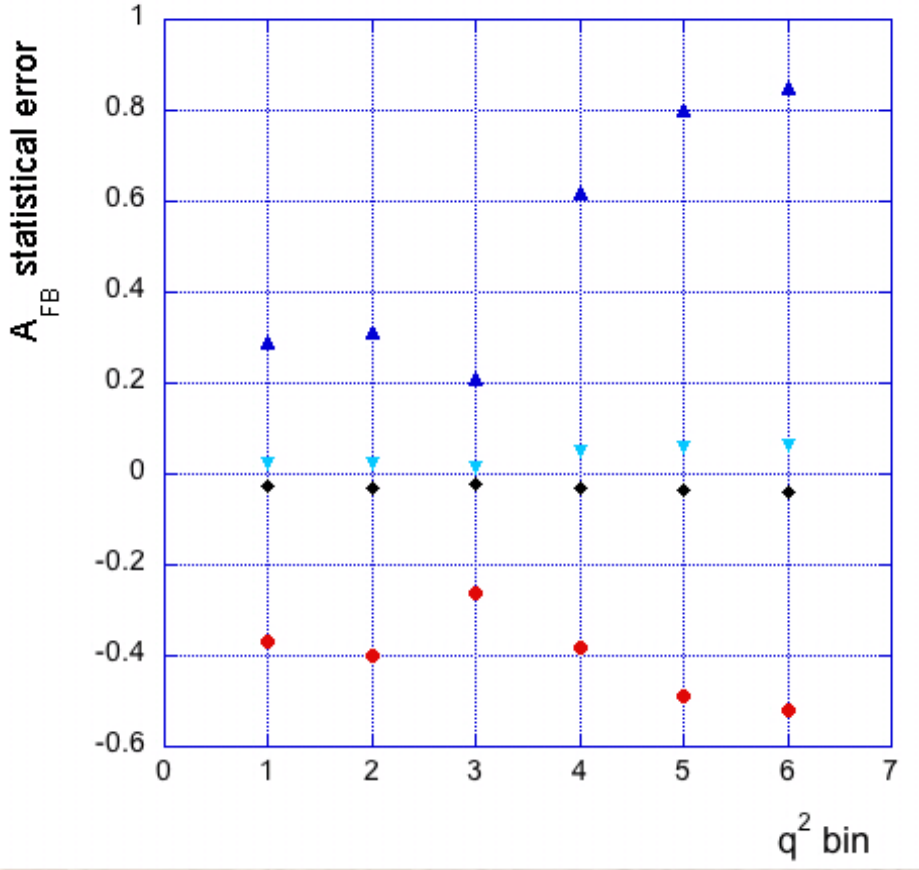
- A_{FB} has been measured in 2 q^2 bins by BABAR and in 6 q^2 bins by Belle and CDF
- We will use results from PRD 79, 031102 (2009) scaled by 1.5 (20% luminosity increase and 30% increase due to reprocessing, PID)
- Good agreement between BABAR, Belle and CDF



A_{FB} in $B \to K^* \ell^+ \ell^-$

- Scale statistical error by sqrt(75,000/425)
- Distribute errors measured in q_{low} into q_1, q_2, q_3 and in q_{high} into q_4, q_5, q_6 by weighting with decay rate

	BABAR	BABAR	SuperB	SuperB
q_{low}	-0.23	0.18	**-0.014**	**0.011**
q_{high}	-0.32	0.52	**-0.020**	**0.032**
q_1	-0.37	0.29	-0.028	0.022
q_2	-0.4	0.31	-0.03	0.023
q_3	-0.26	0.21	-0.02	0.015
q_4	-0.38	0.62	-0.029	0.047
q_5	-0.49	0.8	-0.037	0.06
q_6	-0.52	0.85	-0.039	0.064



- At SuperB statistical errors range between 1.5%-6%

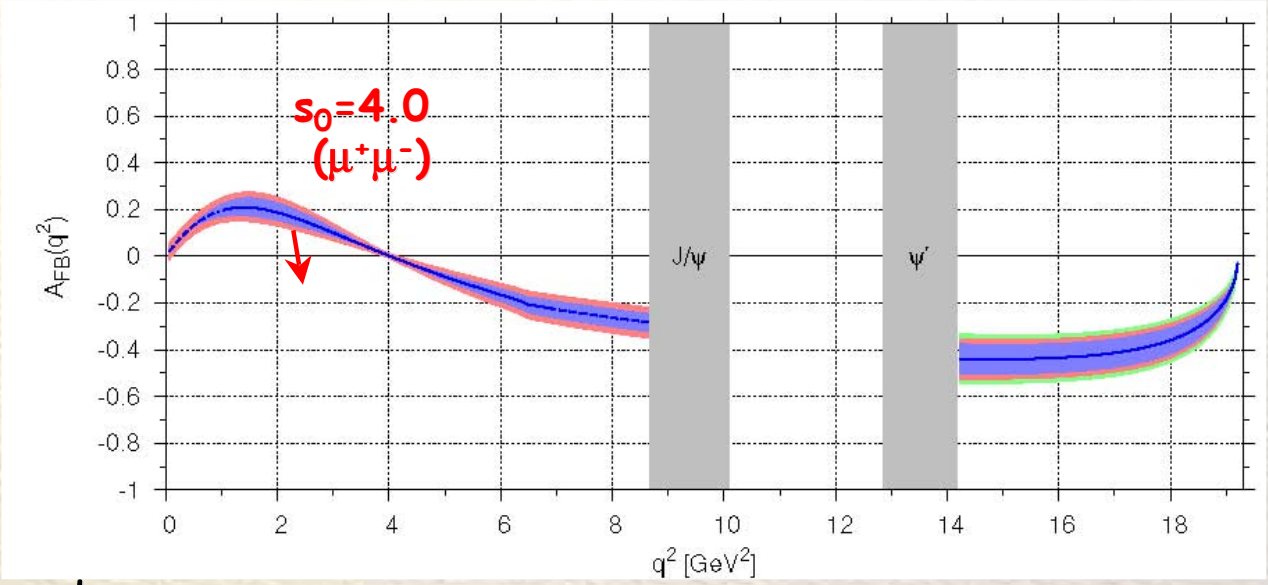
A_{FB} Systematic Errors in $B \to K^* \ell^+ \ell^-$

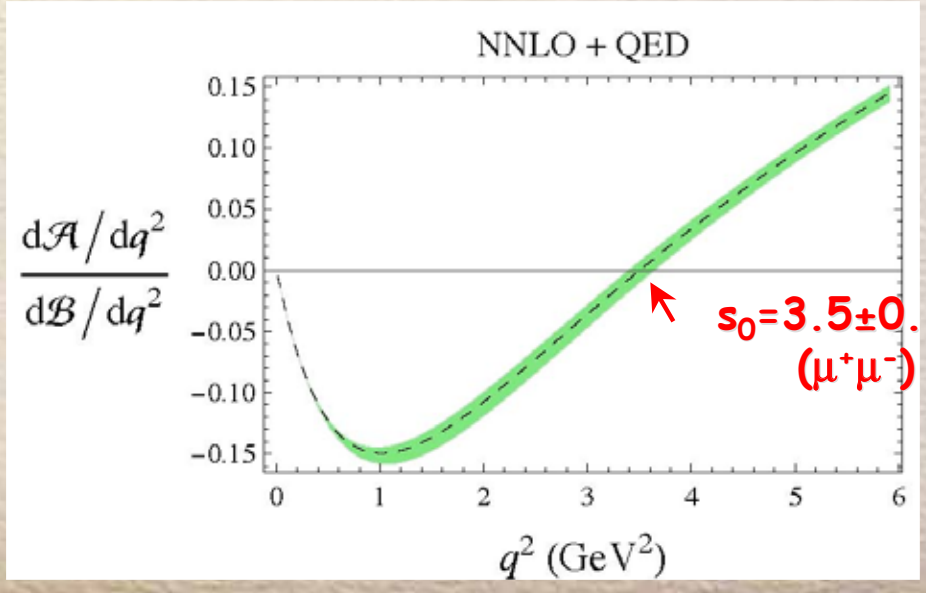
- Look at systematic uncertainties in q_{low} and q_{high}
- Guess improvements of each contributions at SuperB
- Estimate is conservative
- Expect systematic uncertainties of <0.027 for q_{low} and < 0.036 for q_{high}

	q_{low}		q_{high}	
	BABAR	SuperB	BABAR	SuperB
Total sys	0.052	**0.027**	0.074	**0.036**
m_{ES} fit	0.003	0.003	0.002	0.002
F_L fit	0.025	0.012	0.022	0.011
Bg shape	0.017	0.01	0.021	0.11
Signal mode	0.03	0.015	0.038	0.019
Fit bias	0.023	0.013	0.052	0.025
Mis-reco	0.02	0.01	0.02	0.01

A_{FB} Systematic Errors in $B \to K^* \ell^+\ell^-$

- Compare A_{FB} for exclusive and inclusive measurements
- Theory uncertainty in A_{FB} shape is lower in incusive mode than exclusive, except for s_0, why?



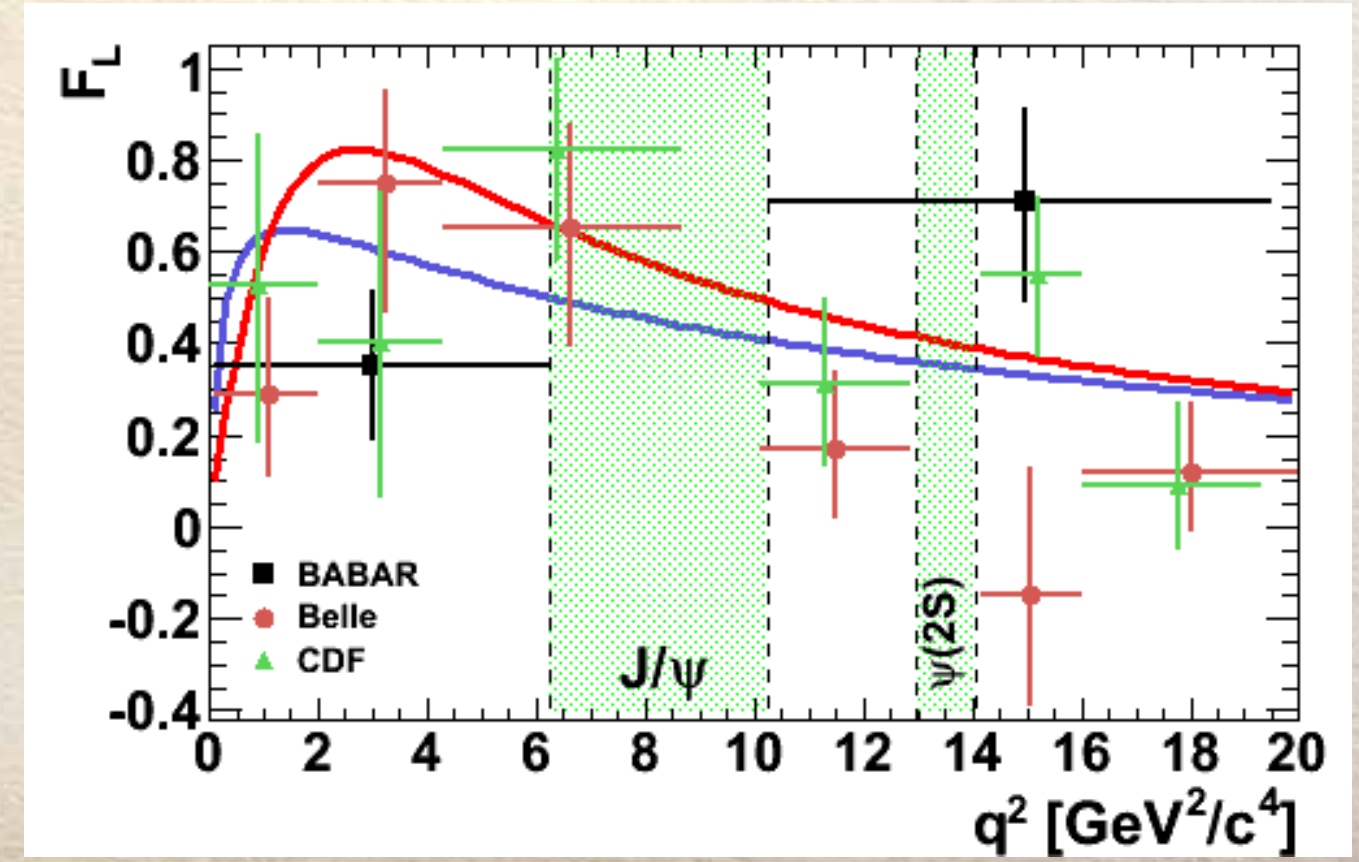


Bobeth, Hiller & van Dyk hep-ph/1006.5013

Huber, Hurth & Lunghi hep-ph/0712.3009

F_L in $B \to K^* \ell^+ \ell^-$

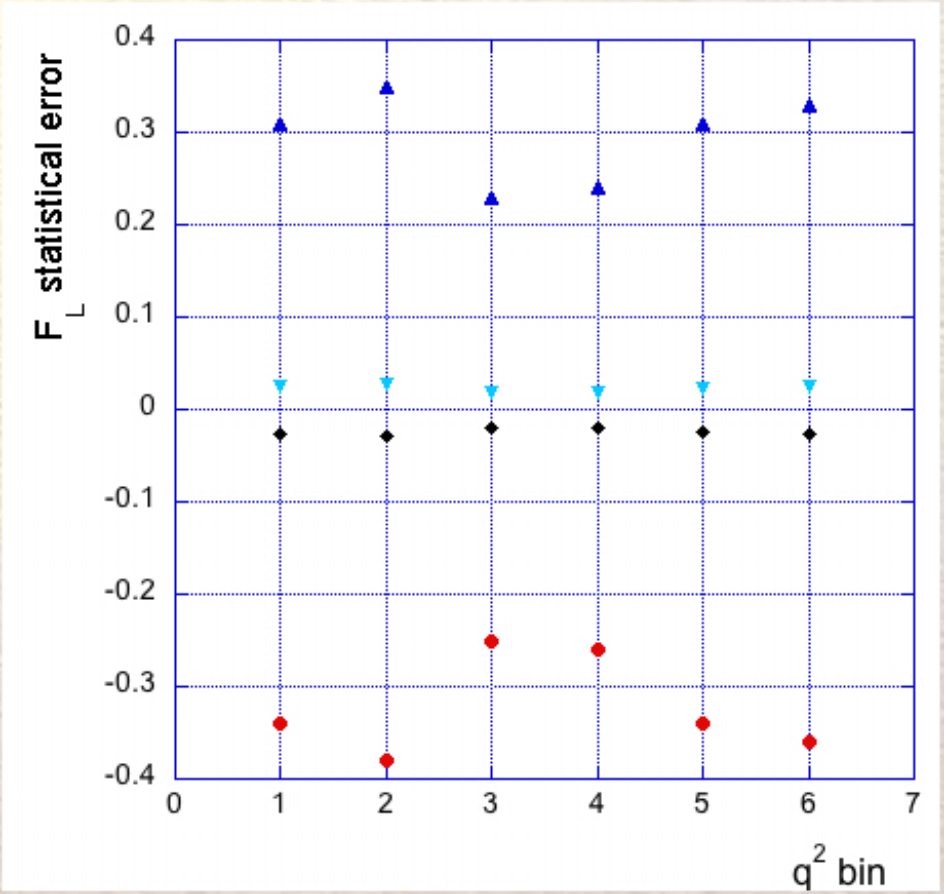
- F_L has been measured in 2 q^2 bins by BABAR and in 6 q^2 bins by Belle and CDF
- We will use results from PRD 79, 031102 (2009) scaled by 1.5 (20% luminosity increase and 30% increase due to reprocessing, PID)
- Good agreement between BABAR, Belle and CDF



F_L in $B \to K^* \ell^+ \ell^-$

- Scale statistical error by sqrt(75,000/425)
- Distribute errors measured in q_{low} into q_1, q_2, q_3 and in q_{high} into q_4, q_5, q_6 by weighting with decay rate

	BABAR	BABAR	SuperB	SuperB
q_{low}	-0.16	0.16	**-0.01**	**0.01**
q_{high}	-0.22	0.20	**-0.014**	**0.012**
q_1	-0.34	0.31	-0.026	0.024
q_2	-0.38	0.35	-0.028	0.026
q_3	-0.25	0.23	-0.019	0.017
q_4	-0.26	0.24	-0.02	0.018
q_5	-0.34	0.31	-0.025	0.023
q_6	-0.36	0.33	-0.027	0.025



- At SuperB statistical errors range between 1%-3%

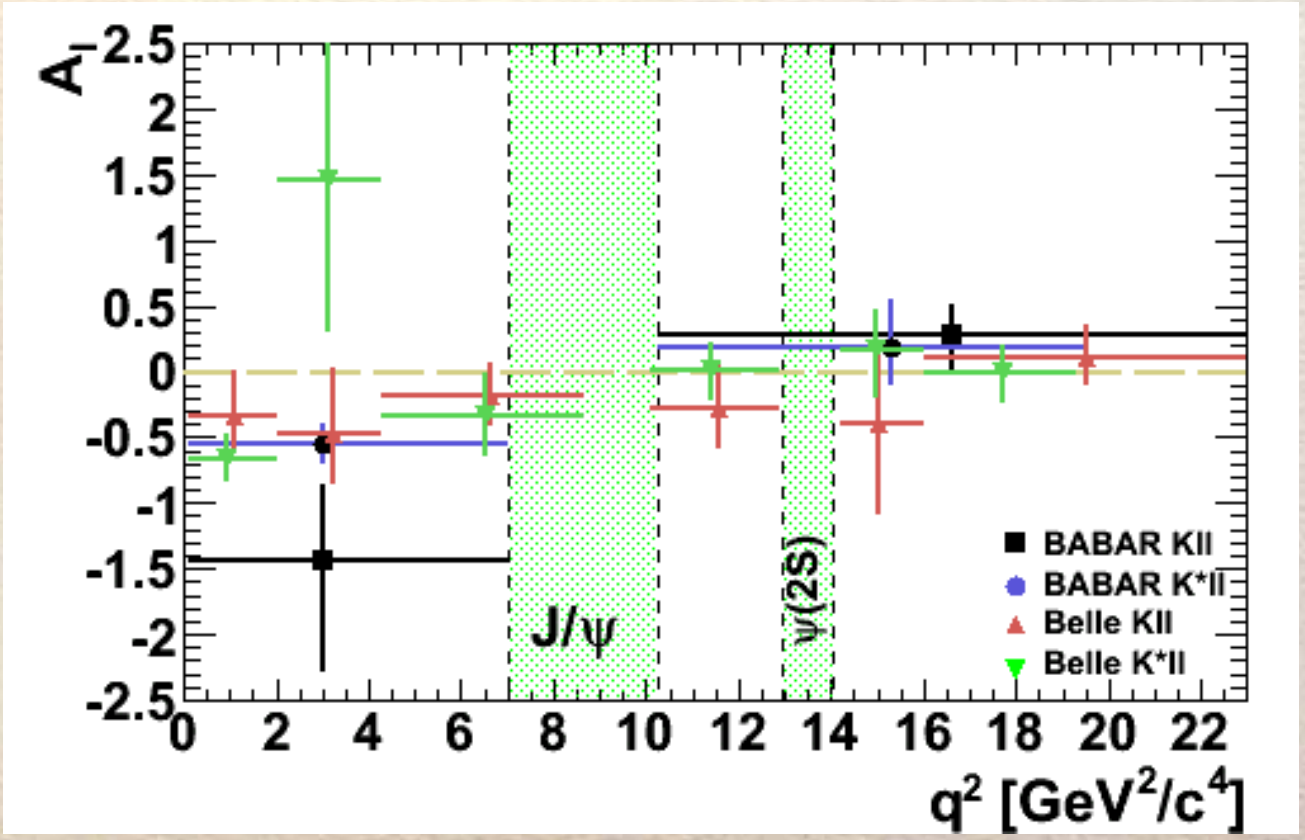
F_L Systematic Errors in $B \to K^* \ell^+ \ell^-$

- Look at systematic uncertainties in q_{low} and q_{high}
- Guess improvements of each contributions at SuperB
- Estimate is conservative
- Expect systematic uncertainties of <0.025 for q_{low} and < 0.025 for q_{high}

	q_{low}		q_{high}	
	BABAR	SuperB	BABAR	SuperB
Total sys	0.041	**0.025**	0.044	**0.025**
m_{ES} fit	0.001	0.001	0.016	0.005
Bg shape	0.011	0.01	0.008	0.008
Signal mode	0.036	0.018	0.034	0.018
Fit bias	0.012	0.01	0.02	0.010
Mis-reco	0.01	0.01	0.01	0.01

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

- A_I was measured in 2 q^2 bins by BABAR and in 6 q^2 bins by Belle
- We will use results from PRL 102, 091803 (2009) scaled by 1.5 (20% luminosity increase and 30% increase due to reprocessing, PID)
- Good agreement between BABAR and Belle
- Belle also agrees with the SM



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

- Scale statistical error by sqrt(75,000/425)
- Distribute errors measured in q_{low} into q_1, q_2, q_3 and in q_{high} into q_4, q_5, q_6 by weighting with decay rate

		K*ll					Kll		
	BABAR	BABAR	SuperB	SuperB		BABAR	BABAR	SuperB	SuperB
q_{low}		0.17		**0.01**			0.56		**0.034**
q_{high}	-0.28		**-0.017**			-0.30		**-0.018**	
q_1		0.27		0.02			0.87		0.066
q_2		0.29		0.022			0.97		0.07
q_3		0.2		0.015			0.64		0.048
q_4	-0.33		-0.025			-0.35		-0.027	
q_5	-0.43		-0.033			-0.46		-0.035	
q_6	-0.46		-0.035			-0.49		-0.037	

Systematic Errors in $A_I(B \to K^{(*)} \ell^+\ell^-)$

- Systematic uncertainties in q_{low} are 0.05 and 0.03 for $B \to K \ell^+\ell^-$ and $B \to K^* \ell^+\ell^-$, respectively
- Systematic uncertainties in q_{high} are 0.03 and 0.04 for $B \to K \ell^+\ell^-$ and $B \to K^* \ell^+\ell^-$, respectively
- At SuperB we expect systematic uncertainties of 0.02-0.03 and 0.01-0.02 in q_{low} for $B \to K \ell^+\ell^-$ and $B \to K^* \ell^+\ell^-$, respectively
- In q_{high}, we expect systematic uncertainties of 0.01-0.02 and 0.02-0.03 in q_{low} for $B \to K \ell^+\ell^-$ and $B \to K^* \ell^+\ell^-$, respectively

Comments

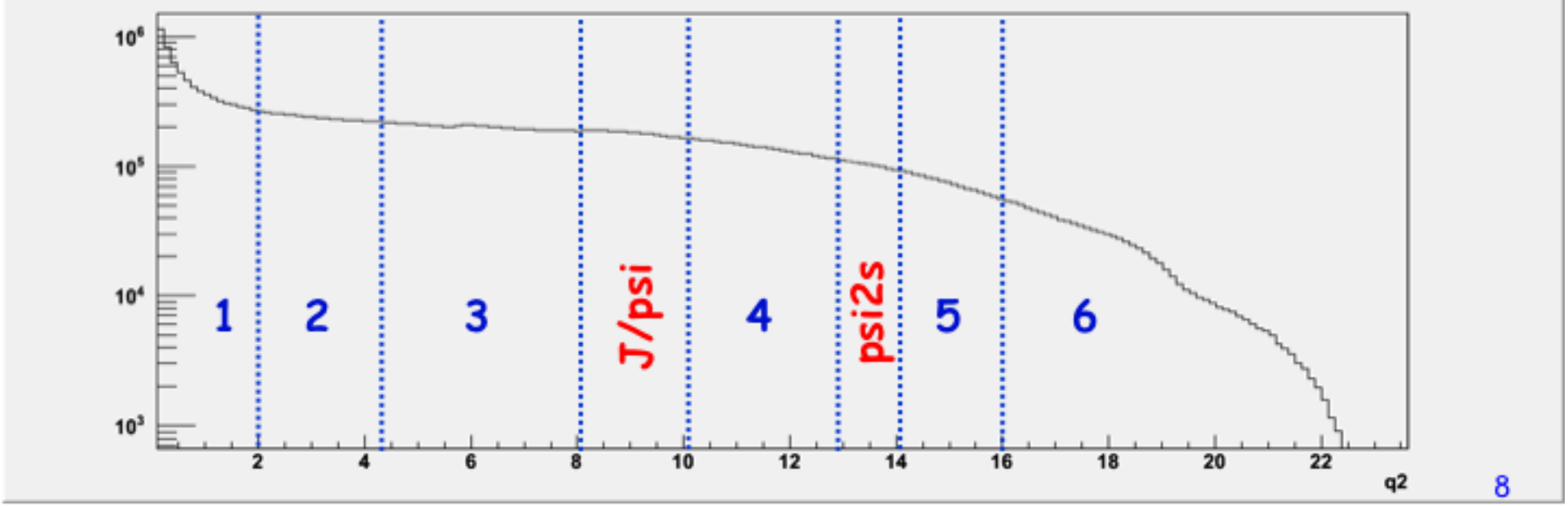
- These estimates assume that the event reconstruction in individual modes has the same efficiency as that in BABAR
- Analysis uses a similar methodology and event optimization as that in BABAR
- ➔ statistical errors scale with sqrt(L)
- Systematic errors are improved by dealing with larger signal yields which improve uncertainties from fitting
  and by trading an optimized selection for worse a statistical error as the systematic error is expected to be dominant
- By performing different extrapolations (scaling data, simulating the SuperB environment) will provide the best range of estimates

Conclusion

- At a luminosity of 75 ab^{-1} at SuperB, the statistical error of A_{FB} in 6 q^2 bins is between 1.5% and 6%, the systematic error is 2.7-3.6%
- For F_L, the statistical error in 6 bins of q^2 is between 1% and 3%, the systematic error is 2.5%
- For A_I, the statistical error lies between 1.5% and 3% for $B \to K^* \ell^+\ell^-$ and 2.7% and 7% for $B \to K^* \ell^+\ell^-$, systematic errors are 1-3%
- At SuperB exclusive and inclusive $B \to X_s \ell^+\ell^-$ modes will be measured with high precision and several are systematics limited
- With this high statistics there is a great potential to explore other observables, e.g. amplitudes in full angular analysis and measure the 11 parameters with high precision
- Thus, there is a great potential to see new physics at $< \mathcal{O}(0.1)$

Backup Slides

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



Number of Events in $B \to (K, K^*, X_s)\, \ell^+\ell^-$

TABLE I: Number of events for $B \to K\ell^+\ell^-$, $B \to K^*\ell^+\ell^-$, $B \to X_s\ell^+\ell^-$ via the sum-of-exclusive modes (SE) and $B \to X_s\ell^+\ell^-$ via the recoil method (RM) for luminosities of 425 fb^{-1} and 75 ab^{-1}. The signal yields are shown for the entire q^2 region, 0.1 GeV^2/c^4 $< q^2 <$ 7.84 GeV^2/c^4 and 1 GeV^2/c^4 $< q^2 <$ 6 GeV^2/c^4. Uncertainties in the yields are of the order of 20%.

	Number of events in 425 fb^{-1}			Expected number of events in 75 ab^{-1}		
Mode	all q^2	0.1–7.84	1–6	all q^2	0.1–7.84	1–6
$K\ell^+\ell^-$	90	42	26	15,900	7,340	4,600
$K^*\ell^+\ell^-$	110	46	24	19,400	8,200	4300
$X_s\ell^+\ell^-$ SL	270	171	101	47,500	30,000	17,900
$X_s\ell^+\ell^-$ RM	49	31	18	8,600	5,500	3250

Expectations for $B \to K \ell^+ \ell^-$

TABLE II: Present and extrapolated statistical and systematic uncertainties of the total branching fraction, partial branching fractions, CP asymmetries, isospin asymmetries, lepton flavor ratio for $B \to K\ell^+\ell^-$ after combining e^+e^- and $\mu^+\mu^-$ modes as well as K^+ and K^0_S modes.

		BABAR (425 fb^{-1})		Super$B$ (75 ab^{-1})	
Observable	q^2 region [GeV^2/c^4]	Stat.	Sys.	Stat.	Sys.
$\sigma\mathcal{B}/\mathcal{B}$	all	0.175	0.05	0.011	0.025-0.035
$\sigma\mathcal{B}/\mathcal{B}$	0.1–7.02	0.20	0.044	0.012	0.022-0.035
$\sigma\mathcal{B}/\mathcal{B}$	10.24–12.96 and > 14.06	0.27	0.052	0.017	0.026-0.039
$\mathcal{R}_K$	all	0.34	0.05	0.021	0.025-0.038
$\mathcal{A}_{CP}$	all	0.18	0.01	0.012	0.008-0.01
$\mathcal{A}_I$	0.1–7.02	0.56	0.05	0.034	0.025-0.035

Expectations for Observables in $B \to K^* \ell^+ \ell^-$

TABLE III: Present and extrapolated statistical and systematic uncertainties of the total branching fraction, partial branching fractions, CP asymmetries, isospin asymmetries, lepton flavor ratio, longitudinal polarization and lepton forward-backward asymmetry for $B \to K^* \ell^+ \ell^-$ after combining e^+e^- and $\mu^+\mu^-$ modes as well as K^{*+} and K^{*0} modes.

		BABAR (425 fb^{-1})		Super*B* (75 ab^{-1})	
Observable	q^2 region [GeV^2/c^4]	Stat.	Sys.	Stat.	Sys.
$\sigma\mathcal{B}/\mathcal{B}$	all	0.162	0.063	0.01	0.032-0.048
$\sigma\mathcal{B}/\mathcal{B}$	0.1–7.02	0.23	0.070	0.014	0.035-0.053
$\sigma\mathcal{B}/\mathcal{B}$	10.24–12.96 and > 14.06	0.24	0.071	0.015	0.036-0.054
$\mathcal{R}_{K*}$	all	0.34	0.07	0.02	0.035-0.048
$\mathcal{A}_{CP}$	all	0.15	0.01	0.009	0.008-0.01
$\mathcal{A}_I$	0.1–7.02	0.17	0.03	0.01	0.015-0.023
$\mathcal{F}_L$	0.1–4	0.15	0.04	0.011	0.02-0.03
$\mathcal{F}_L$	4–7.84	0.14	0.04	0.011	0.02-0.03
$\mathcal{A}_{FB}$	0.1–4	0.14	0.05	0.011	0.025-0.038
$\mathcal{A}_{FB}$	4–7.84	0.14	0.05	0.011	0.025-0.038

Expectations for Observables in $B \to X_s \ell^+ \ell^-$

TABLE IV: Present and extrapolated statistical and systematic uncertainties of the total branching fraction, parti branching fractions, *CP* asymmetries, isospin asymmetries, lepton flavor ratio, and angular observables for $B \to X_s \ell^+ \ell^-$ The first two columns show the results for the sum-of-exclusive modes (SE), the second two columns those for the recc method (RM), respectively. The sum-of-exclusive modes including 28 final states has an additional uncertainty of ~ 10 from the decay model.

		BABAR (425 fb^{-1})				SuperB (75 ab^{-1})			
Observable	q^2 region $[\mathrm{GeV}^2/\mathrm{c}^4]$	Stat. SE	Sys. SE	Stat. RM	Sys. RM	Stat. SE	Sys. SE	Stat. RM	Sys. RM
$\sigma\mathcal{B}/\mathcal{B}$	all	0.11	0.056	0.26	0.06	0.008	0.03-0.05	0.019	0.03-0.05
$\sigma\mathcal{B}/\mathcal{B}$	0.1–1	0.29	0.07	0.69	0.07	0.022	0.04-0.06	0.052	0.04-0.06
$\sigma\mathcal{B}/\mathcal{B}$	1–4	0.23	0.06	0.53	0.06	0.017	0.03-0.05	0.040	0.03-0.05
$\sigma\mathcal{B}/\mathcal{B}$	4–7.84	0.18	0.06	0.43	0.06	0.014	0.03-0.05	0.032	0.03-0.05
$\sigma\mathcal{B}/\mathcal{B}$	10.24–12.96	0.31	0.07	0.73	0.07	0.024	0.04-0.06	0.055	0.04-0.06
$\sigma\mathcal{B}/\mathcal{B}$	>14.06	0.29	0.07	0.69	0.07	0.022	0.04-0.06	0.052	0.04-0.06
$\mathcal{R}_{X_s}$	all	0.21	0.06	0.50	0.06	0.016	0.03-0.05	0.038	0.03-0.05
$\mathcal{R}_{X_s}$	0.1–7.84	0.25	0.06	0.58	0.06	0.019	0.03-0.05	0.044	0.03-0.05
$\mathcal{A}_{CP}$	all	0.06	0.01	0.14	0.01	0.004	0.005-0.008	0.011	0.005-0.008
$\mathcal{A}_{CP}$	0.1–7,84	0.07	0.01	0.16	0.01	0.005	0.005-0.008	0.012	0.005-0.008
$\mathcal{A}_I$	all	0.05	0.06	0.12	0.06	0.004	0.03-0.05	0.009	0.03-0.05
$\mathcal{A}_I$	0.1–7.84	0.06	0.06	0.14	0.06	0.005	0.03-0.05	0.011	0.03-0.05
$\mathcal{H}_L$	0.1–1	0.17	0.04	0.40	0.04	0.013	0.02-0.03	0.030	0.02-0.03
$\mathcal{H}_L$	1–4	0.17	0.04	0.40	0.04	0.013	0.02-0.03	0.030	0.02-0.03
$\mathcal{H}_L$	4–7.84	0.13	0.04	0.27	0.04	0.009	0.02-0.03	0.021	0.02-0.03
$\mathcal{H}_A$	0.1–1	0.22	0.06	0.51	0.06	0.016	0.03-0.05	0.039	0.03-0.05
$\mathcal{H}_A$	1–4	0.22	0.06	0.51	0.06	0.016	0.03-0.05	0.039	0.03-0.05
$\mathcal{H}_A$	4–7.84	0.15	0.06	0.35	0.06	0.011	0.03-0.05	0.026	0.03-0.05

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