Measurement of $B^+ \to K^+ \tau^+ \tau^-$, $B \to K^* l^+ l^-$ and $B \to K \pi^+ \pi^- \gamma$ decays at BaBar

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on behalf of the BaBar collaboration

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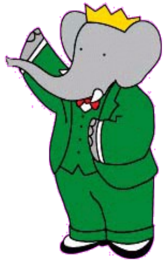

Outline

- Branching fraction of $B^+ \to K^+\tau^+\tau^-$ NEW!
- Angular analysis of $B \to K^* l^+ l^-$ ($l = e, \mu$)
  PRD 93, 052015 (2016)
- Time dependent analysis of $B^0 \to K_s \pi^+ \pi^- \gamma$
- Study of $K^+\pi^+\pi^-$ system in $B^+ \to K^+\pi^+\pi^-\gamma$
  PRD 93, 052013 (2016)
- Summary

Full dataset
471×10^6 $B\bar{B}$ pairs

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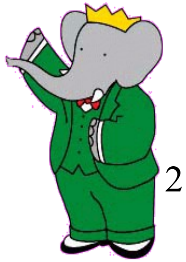
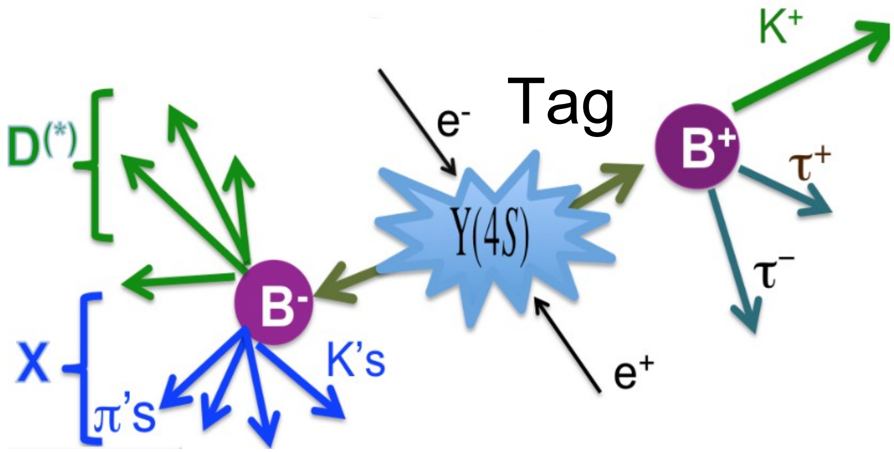
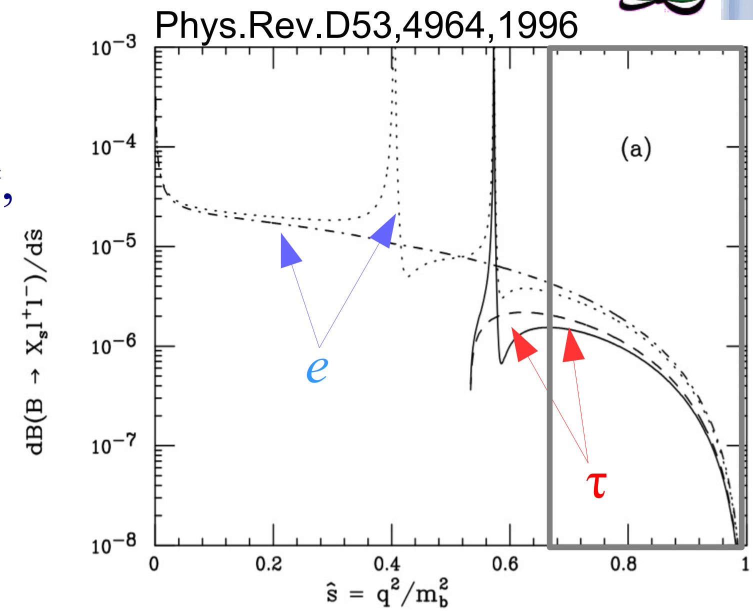


$B^+ \to K^+\tau^+\tau^-$: overview

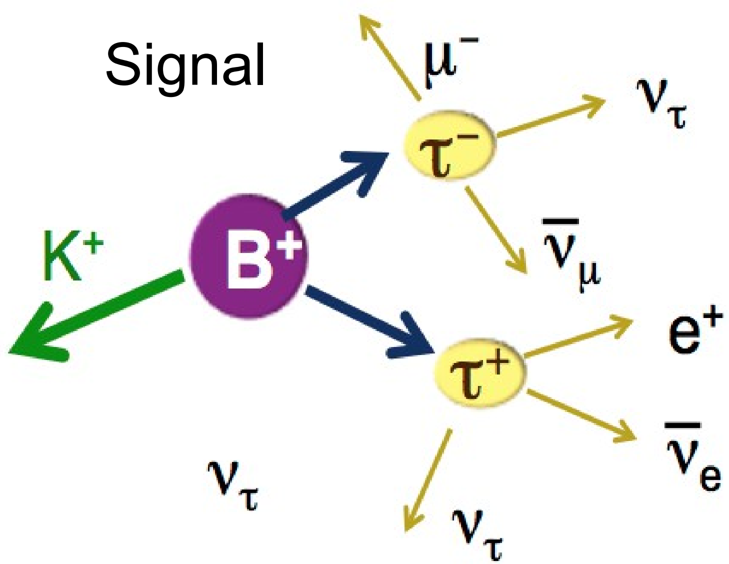
- Heavy τ mass impose upper limit on kaon momentum (~1.5 GeV/c) → no long distance contribution
- Hadronic B_{tag} reconstruction $B_{tag} \to DX$, $D=D^{(*)0}$, $D^{(*)\pm}$, $D_s^{*\pm}$ or J/ψ, X=combination of up to 5 π and/or K's





- Three different final states considered here:

  - Electron: $\tau^+ \to e^+ \nu_e \nu_\tau$, $\tau^- \to e^- \nu_e \nu_\tau$
  - Muon: $\tau^+ \to \mu^+ \nu_\mu \nu_\tau$, $\tau^- \to \mu^- \nu_\mu \nu_\tau$
  - Mixed: $\tau^+ \to e^+ \nu_e \nu_\tau$, $\tau^- \to \mu^- \nu_\mu \nu_\tau$ (+ CC)



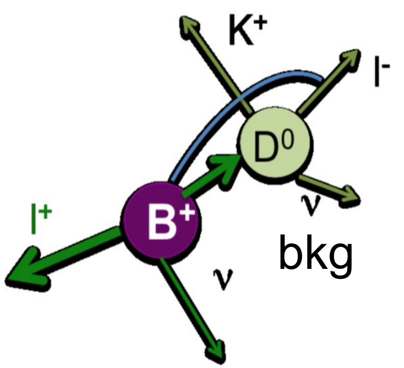
- Cut and count analysis

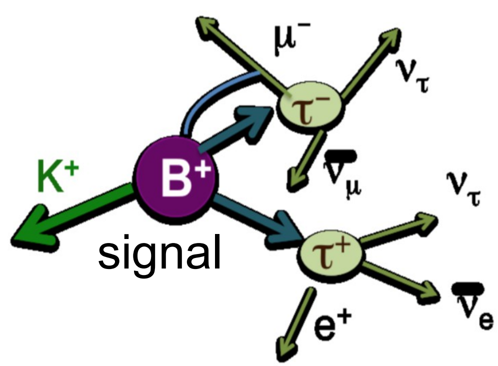
$B^+ \rightarrow K^+\tau^+\tau^-$: signal selection

$$m_{ES} = \sqrt{E^2_{beam} - \vec{p}^2_{B_{tag}}}$$

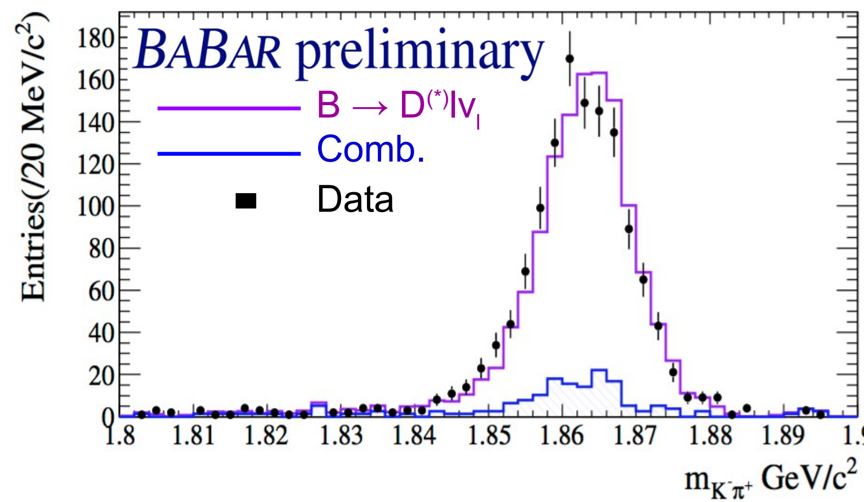
$$\Delta E = E_{beam} - E_{B_{tag}}$$

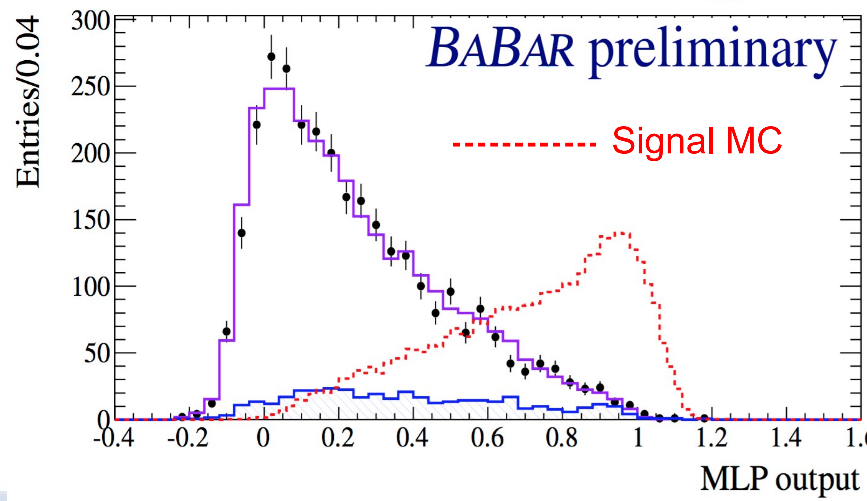
- $m_{ES} > 5.27$ GeV/c^2, $|\Delta E| < 0.12$ GeV and $E_{sig,\ miss} > 0$
- Exactly 3 tracks + PID
- Vetoes: J/ψ on m_{ll}, D^0 on m_{lK}, π^0 on any γ pair
- Main background: $B_{sig} \rightarrow D^{(*)}l\nu_l$ (peak.) + contr. from uds & mis-reco B_{tag} (comb.)
- Background suppression using MLP NN with 7 input variables





- Final cut on MLP chosen in order to get best value on the 90% CL UL





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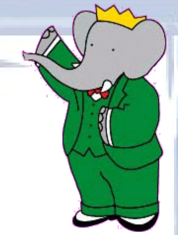
$B^+ \rightarrow K^+\tau^+\tau^-$: results

New!



Event yield:

Mode	ϵ_{sig}	N_{bkg}	N_{obs}
Electron	1.11 ± 0.12	49.4 ± 5.3	45 ± 6.7
Muon	1.29 ± 0.21	45.8 ± 5.1	39 ± 6.2
Electron-Muon	2.05 ± 0.26	59.2 ± 6.2	92 ± 9.6
Combined	4.77 ± 0.42	154.4 ± 9.6	176 ± 13.2

BABAR preliminary

Systematics

Source	Estimate
Theoretical Uncertainty	3%
B_{tag} Yield	1.2% , 1.6%
Particle Identification	~5%
π^0 Veto	3%
MLP Cut	2.6%

Re-weighting reduced di-tau mass distribution according to lattice QCD vs Light Cone Sum Rule model

Varying bkg contributions with toy MC

From MC-data comparison using control samples

$B^+ \rightarrow D^0 l^+ \nu_l$, $D^0 \rightarrow K^+\pi^-$ control sample

Resulting branching fraction:

$$\mathcal{B}(B^+ \rightarrow K^+\tau^+\tau^-) = (1.31^{+0.66}_{-0.61}(\text{stat.})^{+0.35}_{-0.25}(\text{sys.})) \times 10^{-3}$$

Upper limit at the 90 % confidence level: 2.25×10^{-3}

BABAR preliminary

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

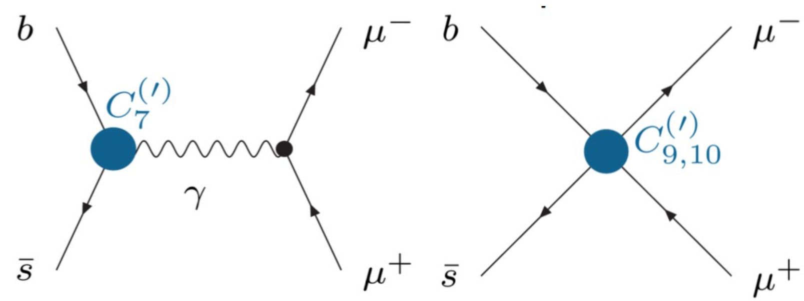
- Effective Hamiltonian factorizes short-distance from long-distance effects

Operator Product Expansion:

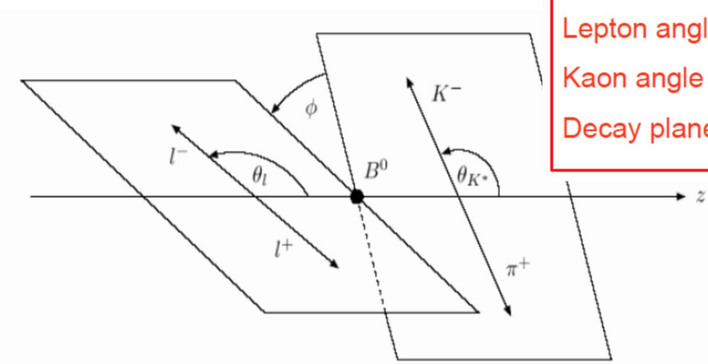
$$H_{Eff} \propto \sum_{i=1}^{10} C_i O_i$$

Short-distance/ perturbative (C_i)

Long-distance/ non-perturbative (O_i)



- Three short-distance Wilson coefficients
  - C^7_{eff} from photon penguin ($b \to s\gamma$) ~0.33
  - C^9_{eff} (C^{10}_{eff}) from vector (axial-vector) parts of the Z, W box



3 angles

Lepton angle θ_l

Kaon angle θ_K

Decay plane angle ϕ

- Decay rate can be parametrized by φ, θ_K and θ_l

- Integrating out φ, and θ_K or θ_l alternately:

$$\frac{1}{\Gamma(q^2)}\frac{d\Gamma}{d(\cos\theta_K)} = \frac{3}{2}F_L(q^2)\cos^2\theta_K + \frac{3}{4}(1-F_L(q^2))(1-\cos^2\theta_K)$$

$$\frac{1}{\Gamma(q^2)}\frac{d\Gamma}{d(\cos\theta_\ell)} = \frac{3}{4}F_L(q^2)(1-\cos^2\theta_l) + \frac{3}{8}(1-F_L(q^2))(1+\cos^2\theta_l) + \mathcal{A}_{FB}(q^2)\cos\theta_l\,.$$

F_L: K^* longitudinal polarization

A_{FB}: lepton forward-backward asymmetry

$B \rightarrow K^* l^+ l^-$: final states

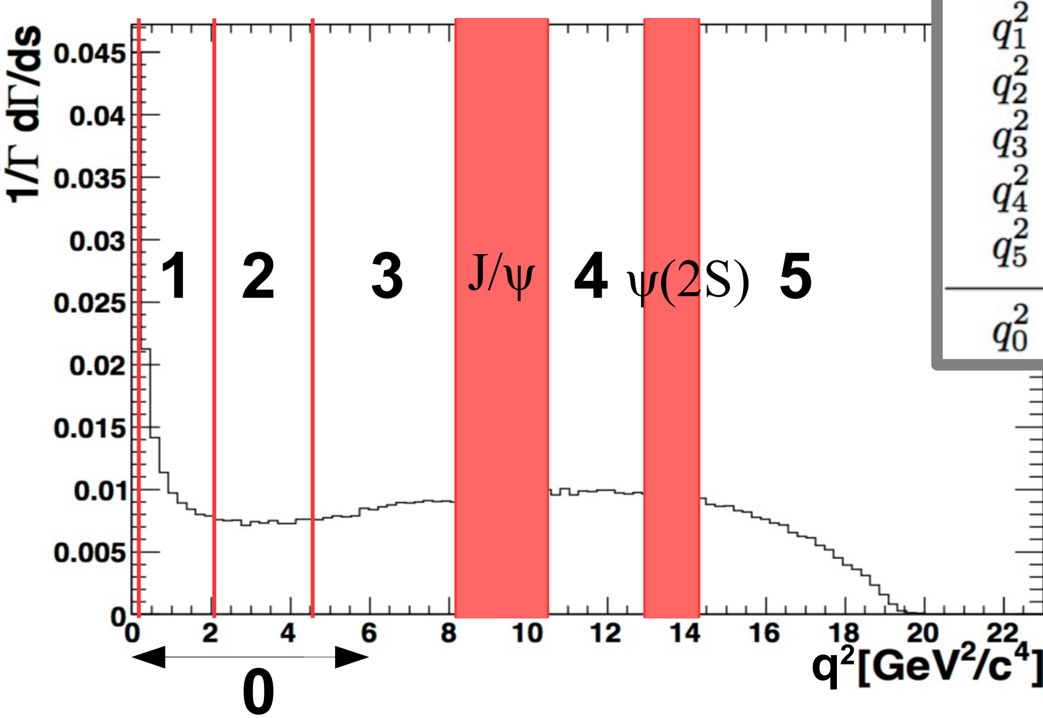
Reconstructed final states:

- Mode 1 - $B^+ \rightarrow K^{*+} \mu^+ \mu^- (K^{*+} \rightarrow K_S \pi^+)$
- Mode 2 - $B^0 \rightarrow K^{*0} \mu^+ \mu^- (K^{*0} \rightarrow K^+ \pi^-)$
- Mode 3 - $B^+ \rightarrow K^{*+} e^+ e^- (K^{*+} \rightarrow K^+ \pi^0)$
- Mode 4 - $B^+ \rightarrow K^{*+} e^+ e^- (K^{*+} \rightarrow K_S \pi^+)$
- Mode 5 - $B^0 \rightarrow K^{*0} e^+ e^- (K^{*0} \rightarrow K^+ \pi^-)$

Signal modes:

$B \rightarrow K^* l^+ l^-$	Modes: 1+2+3+4+5
$B^0 \rightarrow K^{*0} l^+ l^-$	Modes: 2+5
$B^+ \rightarrow K^{*+} l^+ l^-$	Modes: 1+3+4

q^2 bin	q^2 min (GeV^2/c^4)	q^2 max (GeV^2/c^4)
q_1^2	0.10	2.00
q_2^2	2.00	4.30
q_3^2	4.30	8.12
q_4^2	10.11	12.89
q_5^2	14.21	$(m_B - m_{K^*})^2$
q_0^2	1.00	6.00



$B \to K^* l^+ l^-$: signal selection

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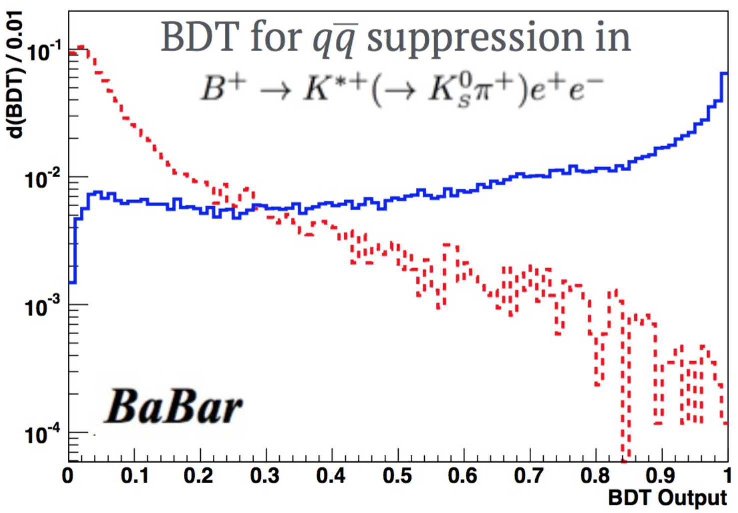
- e, μ, K, π particle ID, $p_l > 0.3$ GeV/c
- $0.7 < M_{K\pi} < 1.1$ GeV/c^2, $0.115 < M(\pi^0) < 0.155$ GeV/c^2
- Bagged decision trees (BDTs) used to construct LHratio L_R used in fitting, along with m_{ES}, $M_{K\pi}$
- Separate BDTs for low (<J/ψ) and high q^2 regions
- J/ψ, ψ(2S) regions vetoed, use as control samples

$$L_R \equiv \frac{\mathcal{P}_{\rm sig}}{\mathcal{P}_{\rm sig} + \mathcal{P}_{\rm bkg}}$$



- F_L and A_{FB} are extracted from a simultaneous fit across K^* final states in 3 steps:
- 1st fit: $m_{ES} > 5.20$, $M_{K\pi}$, L_R for every mode separately; fix results for fits 2,3
- 2nd fit: $m_{ES} > 5.27$ dataset, fit $\cos(\theta_K)$, extract F_L, fix results for fit 3
- 3rd fit: fit $\cos(\theta_l)$, extract A_{FB}

$B \to K^* l^+ l^-$: fit model

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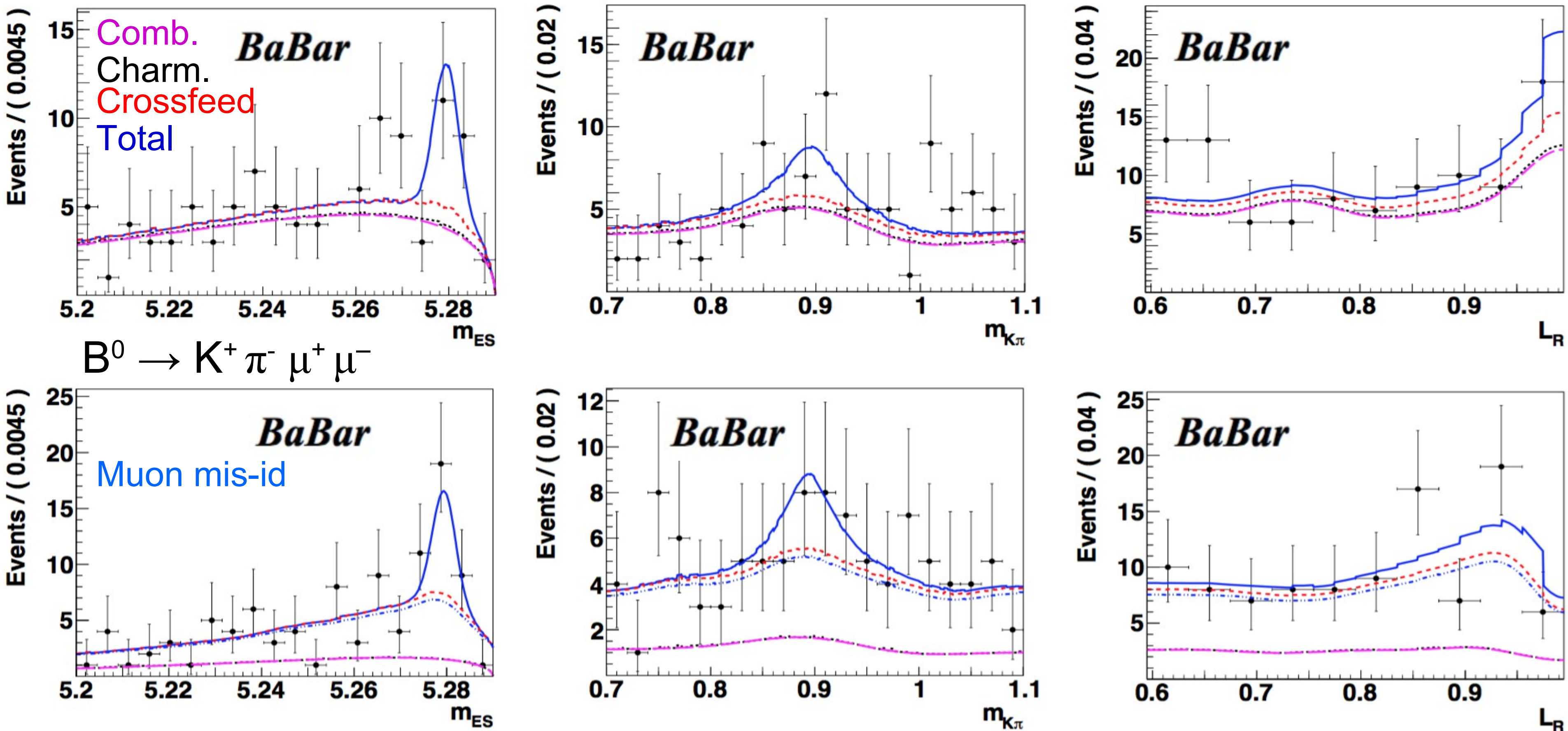
- Several classes of events: truth-matched signal, cross-feed signal, physics backgrounds, combinatoric background, hadronic mis-id backgrounds (μμ states only)

$B^0 \to K^+ \pi^- e^+ e^-$

$B^0 \to K^+ \pi^- \mu^+ \mu^-$



Signal yield:

Mode	q^2_0	q^2_1	q^2_2	q^2_3	q^2_4	q^2_5
$B \to K^* \ell^+ \ell^-$	40.8 ± 8.4	31.7 ± 7.1	11.9 ± 5.5	21.3 ± 8.5	31.9 ± 9.2	33.2 ± 7.8
$B^+ \to K^{*+} \ell^+ \ell^-$	17.7 ± 5.2	8.7 ± 4.1	3.8 ± 4.0	7.7 ± 5.6	9.0 ± 4.8	9.4 ± 4.2
$B^0 \to K^{*0} \ell^+ \ell^-$	23.1 ± 6.6	22.9 ± 5.8	8.1 ± 3.8	13.7 ± 6.4	22.8 ± 7.8	23.8 ± 6.6

$B \to K^*l^+l^-$: fit & systematics

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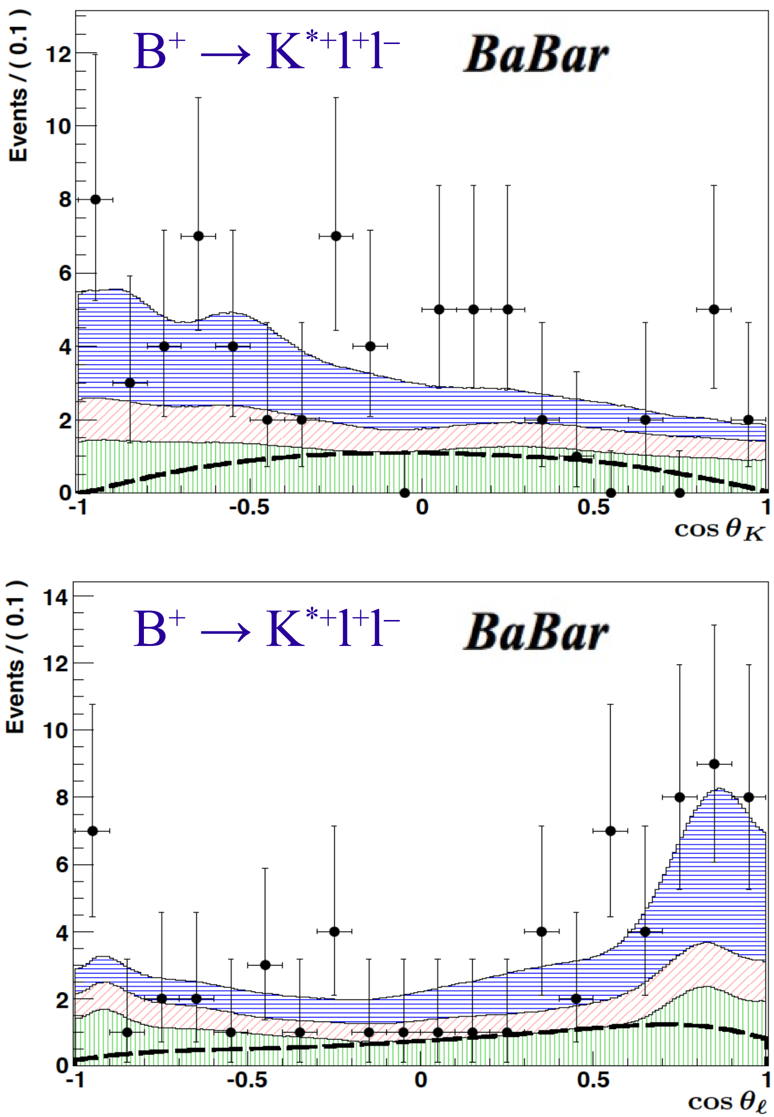
$1.0 < q_0^2 < 6.0$ GeV^2/c^4



Systematic contributions:

- purely statistical uncertainties in the parameters obtained from the initial 3-d m_{ES}, $m_{K\pi}$ fit which are used in the angular fits
- F_L statistical uncertainty, which is propagated into the A_{FB} fit
- modeling of the random combinatorial background pdfs
- signal angular efficiencies
- Several other sources studied → negligible

$B^+ \to K_S\pi^+e^+e^-$

$B^+ \to K_S\pi^+\mu^+\mu^-$ — — Signal

$B^+ \to K^+\pi^0e^+e^-$

$B \to K^{*}l^{+}l^{-}$: results

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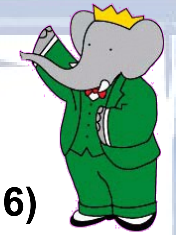
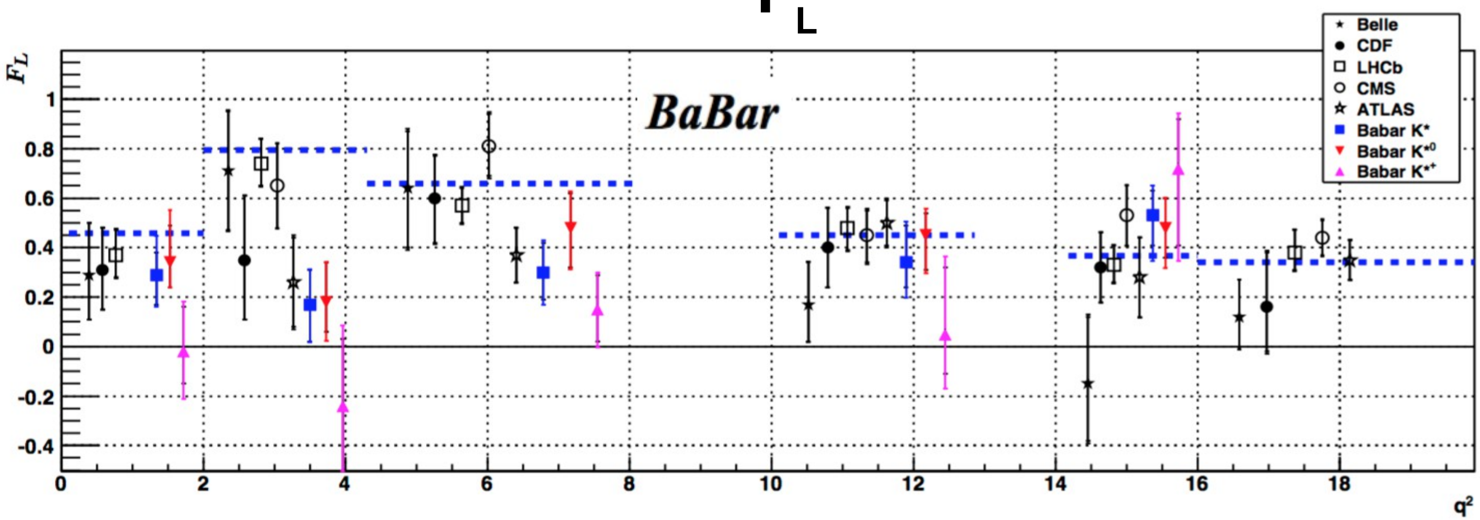
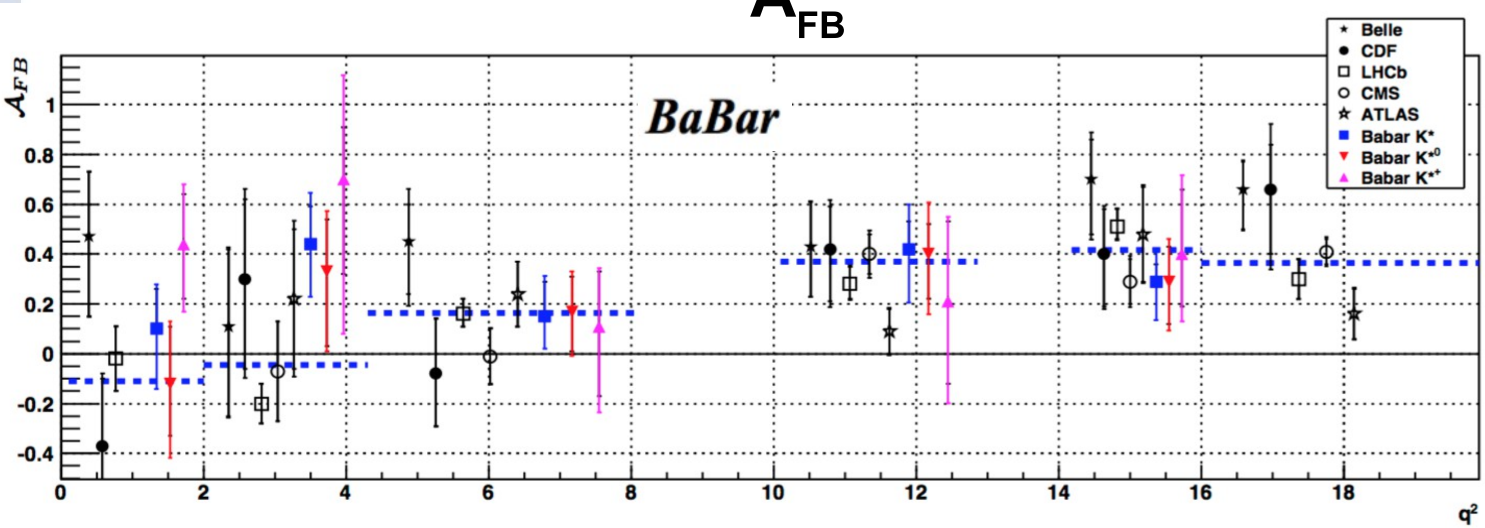
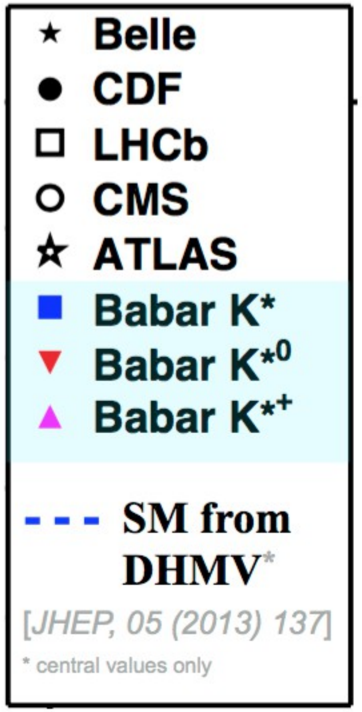


F_L



A_{FB}





Belle [PRL103(2009)171801]
CDF [PRL108(2012)081807]
LHCb [JHEP02(2016)104]
CMS [PLB753(2016)424]
[ATLAS-CONF-2013-038]

Broad agreement with other measurements

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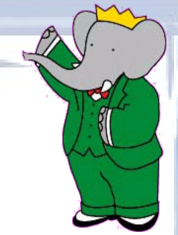
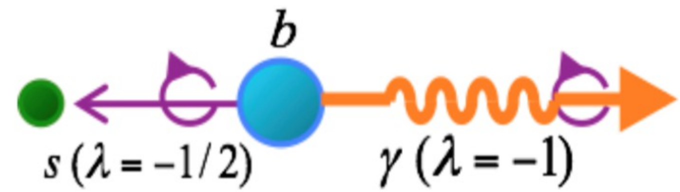
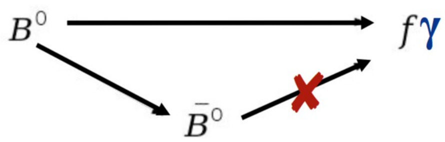
$B \to K\pi^+\pi^-\gamma$: overview



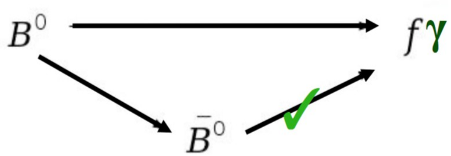
- In SM: left-handed quarks, right-handed antiquarks → left handed photon
- New Physics, if present in the loop may enhance right-handed photons

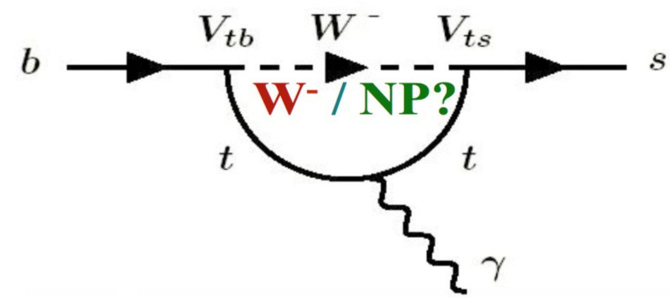


SM $\Rightarrow b \to s\gamma_L$ or $\bar{b} \to \bar{s}\gamma_R \Rightarrow$
CP asymmetry parameters ≈ 0



NP $\Rightarrow b \to s\gamma_{L,R}$ or $\bar{b} \to \bar{s}\gamma_{R,L} \Rightarrow$
CP asymmetry parameters ≠ 0





$$\mathcal{A}_{CP}(\Delta t) = \frac{\Gamma(\overline{B}^0(\Delta t) \to f_{CP}\gamma) - \Gamma(B^0(\Delta t) \to f_{CP}\gamma)}{\Gamma(\overline{B}^0(\Delta t) \to f_{CP}\gamma) + \Gamma(B^0(\Delta t) \to f_{CP}\gamma)}$$
$$= \mathcal{S}_{f_{CP}} \sin(\Delta m_d \Delta t) - \mathcal{C}_{f_{CP}} \cos(\Delta m_d \Delta t)$$

Observable

$$\mathcal{S}_{f_{CP}} \overset{SM}{\propto} \frac{m_s}{m_b} \simeq 0.02$$

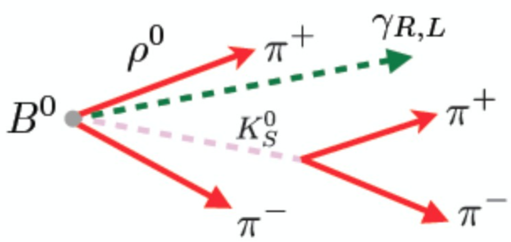
Goal: measurement of S_f in $B \to K_S\rho^0\gamma$ decays

$B \to K\pi^+\pi^-\gamma$: overview

- Problem: irreducible background from $B \to K^*\pi\gamma$ (non CP-eigenstates)

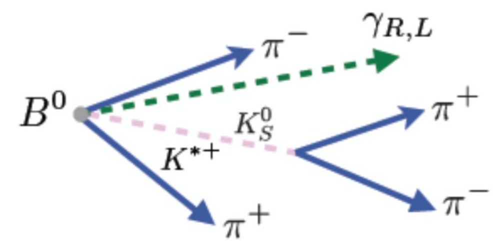
Signal

$B^0 \to K_S\,\rho^0(\to\pi^-\pi^+)\,\gamma$:



Bkg

$B^0 \to K^{*\pm}(\to K_S\,\pi^\pm)\,\pi^\mp\,\gamma$:



- $S_{K\rho\gamma}$ is diluted by:

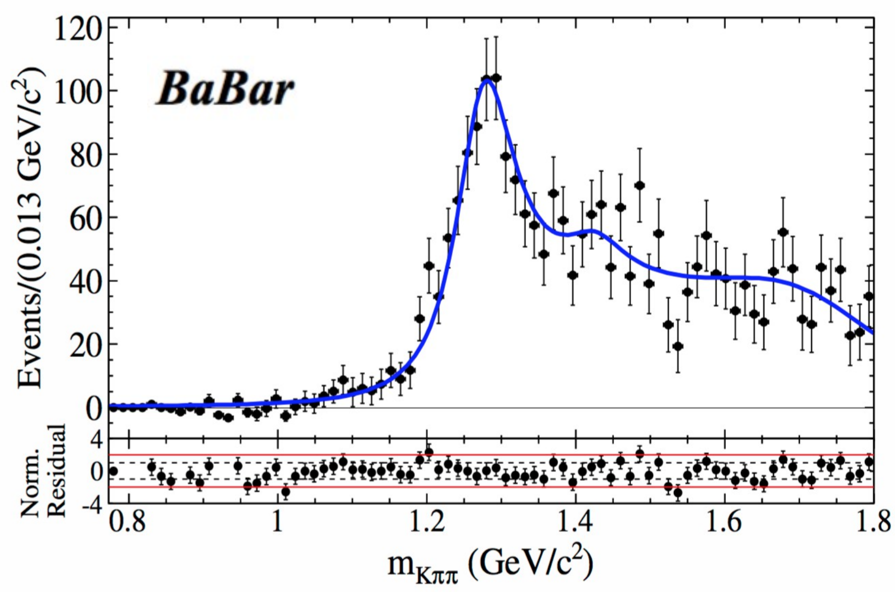
$$\mathcal{D}_{K_S^0\rho\gamma} \equiv \frac{\mathcal{S}_{K_S^0\pi^+\pi^-\gamma}}{\mathcal{S}_{K_S^0\rho\gamma}} = \frac{\int\left[\left|A_{\rho K_S^0}\right|^2 - \left|A_{K^{*+}\pi^-}\right|^2 - \left|A_{(K\pi)_0^{*+}\pi^-}\right|^2 + 2\Re\left(A^*_{\rho K_S^0}A_{K^{*+}\pi^-}\right) + 2\Re\left(A^*_{\rho K_S^0}A_{(K\pi)_0^{*+}\pi^-}\right)\right]dm^2}{\int\left[\left|A_{\rho K_S^0}\right|^2 + \left|A_{K^{*+}\pi^-}\right|^2 + \left|A_{(K\pi)_0^{*+}\pi^-}\right|^2 + 2\Re\left(A^*_{\rho K_S^0}A_{K^{*+}\pi^-}\right) + 2\Re\left(A^*_{\rho K_S^0}A_{(K\pi)_0^{*+}\pi^-}\right)\right]dm^2}$$

J. Hebinger, E. Kou and F.S. Yu, LAL-15-75 (2015)

- Need amplitude analysis to calculate dilution factor
- We use $B^+ \to K^+\pi^+\pi^-\gamma$ to determine $D_{K\rho\gamma}$ because of the higher signal yield assuming isospin symmetry
- $K^+\pi^+\pi^-\gamma$ final state is produced by resonances that decay via intermediate $K^{*0}(892)\pi^+$ or $K^+\rho^0$ states $\to$ determine 3-body resonance content of $m_{K\pi\pi}$

$B^+ \to K^+\pi^+\pi^-\gamma$ analysis

- Unbinned maximum likelihood fit to m_{ES}, ΔE and Fisher discriminant to extract $B^+ \to K^+\pi^+\pi^-\gamma$ signal yield
  Fisher, Annals Eugen. 7, 179 (1936)
- Extract signal $m_{K\pi\pi}$, $m_{K\pi}$ & $m_{\pi\pi}$ spectra using sPlot technique
  Pivk et al., NIM A555, 356 (2005)
- Fit model: $m_{K\pi\pi}$ distribution as a coherent sum of 5 resonances [$K_1(1270)^+$, $K_1(1400)^+$, $K^*(1410)^+$, $K^*(1680)^+$, $K^*_2(1430)^+$] by relativistic B-W line shapes
- We measure a branching fraction of $\mathcal{B}(B^+ \to K^+\pi^+\pi^-\gamma) = (24.5 \pm 0.9 \pm 1.2) \times 10^{-6}$



Mode	$\mathcal{B}(B^+ \to \text{Mode}) \times \mathcal{B}(K_{res} \to K^+\pi^+\pi^-) \times 10^{-6}$	$\mathcal{B}(B^+ \to \text{Mode}) \times 10^{-6}$	Previous world average [17] ($\times 10^{-6}$)
$B^+ \to K^+\pi^+\pi^-\gamma$	$\cdots$	$24.5 \pm 0.9 \pm 1.2$	27.6 ± 2.2
$K_1(1270)^+\gamma$	$14.5^{+2.1+1.2}_{-1.4-1.2}$	$44.1^{+6.3+3.6}_{-4.4-3.6} \pm 4.6$	43 ± 13
$K_1(1400)^+\gamma$	$4.1^{+1.9+1.2}_{-1.2-1.0}$	$9.7^{+4.6+2.8}_{-2.9-2.3} \pm 0.6$	< 15 at 90% CL
$K^*(1410)^+\gamma$	$11.0^{+2.2+2.1}_{-2.0-1.1}$	$27.1^{+5.4+5.2}_{-4.8-2.6} \pm 2.7$	n/a
$K_2^*(1430)^+\gamma$	$1.2^{+1.0+1.2}_{-0.7-1.5}$	$8.7^{+7.0+8.7}_{-5.3-10.4} \pm 0.4$	14 ± 4
$K^*(1680)^+\gamma$	$15.9^{+2.2+3.2}_{-1.9-2.4}$	$66.7^{+9.3+13.3}_{-7.8-10.0} \pm 5.4$	< 1900 at 90% CL

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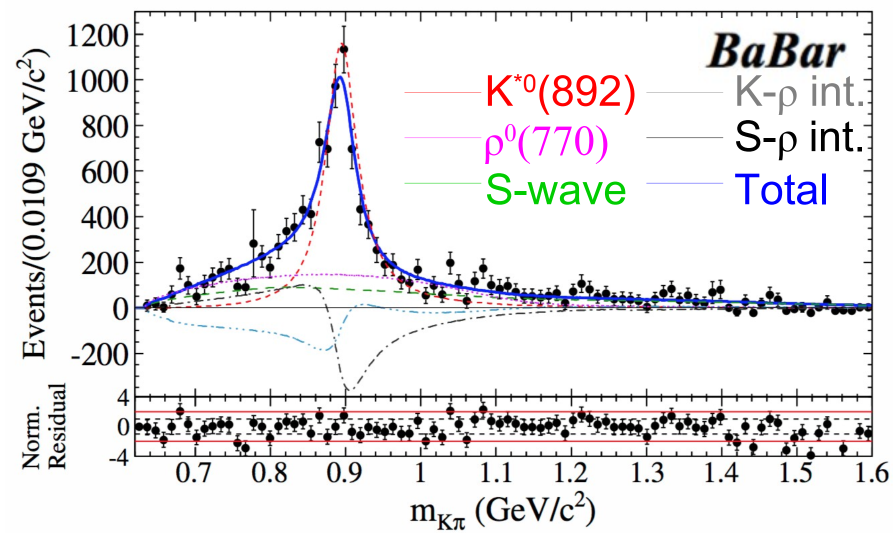
$K\pi$ analysis in $B \to K\pi\pi\gamma$

- We extract fit fractions and branching fractions from ML fit to $m_{K\pi}$ sPlot
- For $(K\pi)_R$, we include $K^*_0(892)$ (P-wave) and 0^+ (S-wave) components, for $(\pi\pi)_R$ we include $\rho^0(770)$ (P-wave)
- We include also $K\pi$ and $\pi\pi$ P- and S-wave interference terms respectively
- Model $K^{*0}(892)$ by relativistic BW, $\rho^0(770)$ by Gounaris-Sakurai line shape and 0^+ by LASS (R + NR) parameterization
- We measure dilution factor for $0.6<m_{\pi\pi}<0.9$, $m_{K\pi}<0.845$, $m_{K\pi}>0.945$ and $m_{K\pi\pi}<1.8$ GeV/c^2

$$\mathcal{D}_{K^0_S\rho\gamma} = -0.78^{+0.19}_{-0.17}$$



Mode	$\mathcal{B}(B^+ \to \text{Mode}) \times \mathcal{B}(R \to h\pi) \times 10^{-6}$	$\mathcal{B}(B^+ \to \text{Mode}) \times 10^{-6}$	Previous world average [17] ($\times 10^{-6}$)
$K^*(892)^0\pi^+\gamma$	$15.6 \pm 0.6 \pm 0.5$	$23.4 \pm 0.9^{+0.8}_{-0.7}$	20^{+7}_{-6}
$K^+\rho(770)^0\gamma$	$8.1 \pm 0.4^{+0.8}_{-0.7}$	$8.2 \pm 0.4 \pm 0.8 \pm 0.02$	< 20 at 90% CL
$(K\pi)^{*0}_0\pi^+\gamma$	$10.3^{+0.7+1.5}_{-0.8-2.0}$	…	n/a
$(K\pi)^0_0\pi^+\gamma$ (NR)	…	$9.9 \pm 0.7^{+1.5}_{-1.9}$	< 9.2 at 90% CL
$K^*_0(1430)^0\pi^+\gamma$	$0.82 \pm 0.06^{+0.12}_{-0.16}$	$1.32^{+0.09+0.20}_{-0.10-0.26} \pm 0.14$	n/a

- This is the first observation of $(K\pi)^{*0}_0\pi^+\gamma$ NR-contribution

PRD 93, 052013 (2016)

$B^0 \to K_S\pi^+\pi^-\gamma$: results

PRD 93, 052013 (2016)

- Selection of $B^0 \to K_S\pi^+\pi^-\gamma$ events is identical to that of the $B^+ \to K^+\pi^+\pi^-\gamma$ mode $|m_{\pi\pi} - m_{Ks}| < 11$ MeV/c^2
- We perform an unbinned extended ML fit to extract $B^0 \to K_S\pi^+\pi^-\gamma$ event yield along with time-dependent CP asymmetry parameters $S_{K\pi\pi\gamma}$ and $C_{K\pi\pi\gamma}$
- We find: $N_{\rm sig} = 243 \pm 24^{+21}_{-17}$

signal candidates, resulting in

$$\mathcal{B}(B^0 \to K^0\pi^+\pi^-\gamma) = (20.5 \pm 2.0^{+2.6}_{-2.2}) \times 10^{-6}$$

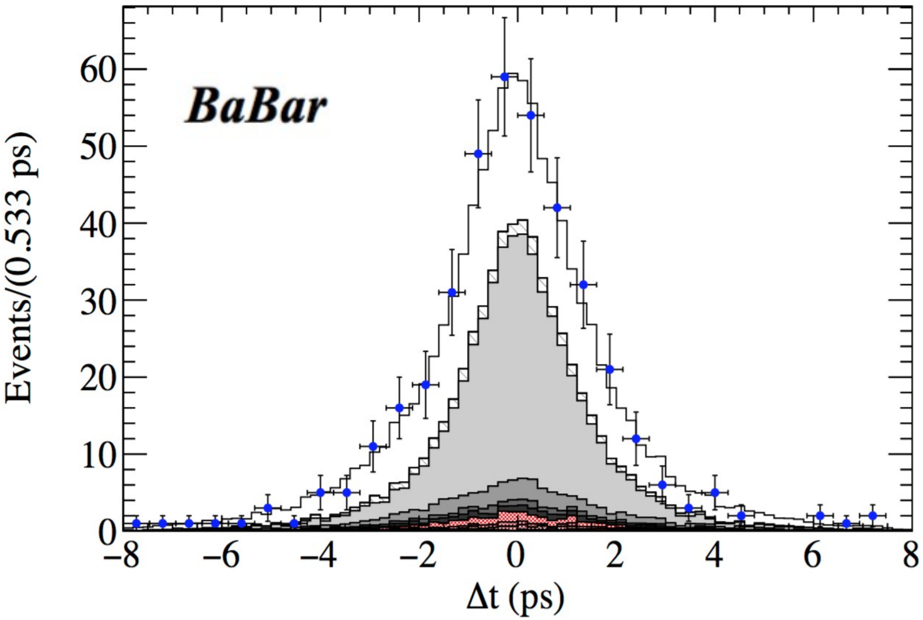
$$\mathcal{S}_{K^0_S\pi^+\pi^-\gamma} = 0.14 \pm 0.25 \pm 0.03$$

$$\mathcal{C}_{K^0_S\pi^+\pi^-\gamma} = -0.39 \pm 0.20^{+0.03}_{-0.02}.$$

and using previously calculated $D_{K\rho\gamma}$

$$\mathcal{S}_{K^0_S\rho\gamma} = -0.18 \pm 0.32^{+0.06}_{-0.05}$$

in agreement with SM



Summary

- Babar continues to produce exciting physics results

- First search for $B^+ \rightarrow K^+ \tau^+ \tau^-$, no significant signal is observed and an upper limit at 90% CL is set

- First results for the angular analysis of $B^+ \rightarrow K^{*+} l^+ l^-$

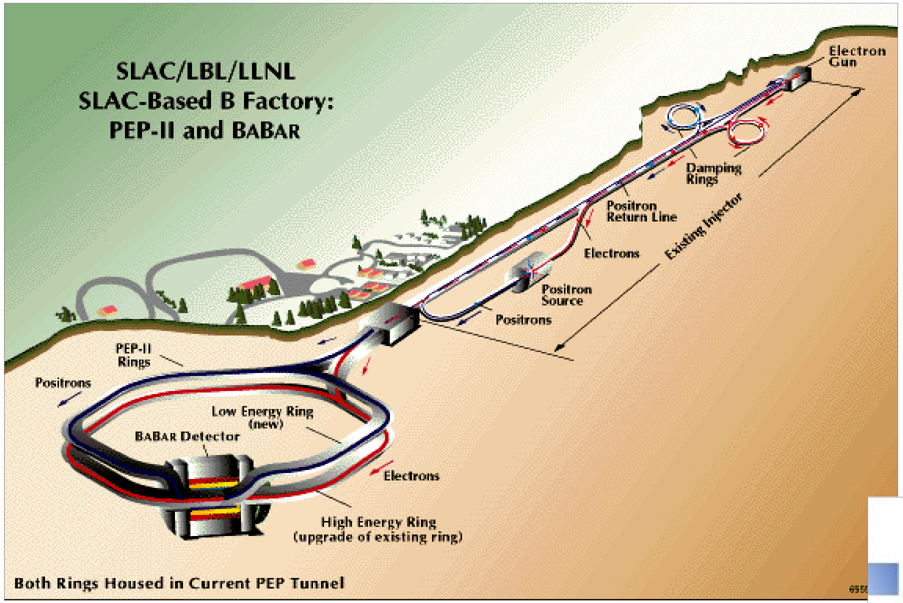
- Inclusive analysis of $B \rightarrow K^* l^+ l^-$ broad agreement with SM and other experimental results, some tension with SM in low energy bins

- We have measured the time dependent asymmetry parameter $S_{K\rho\gamma}$ and found it to be in agreement with SM and previous measurements

- We have studied the decay $B^+ \rightarrow K^+\pi^+\pi^-\gamma$ and we have measured the intermediate resonant amplitudes and their branching fractions, many of which for the first time (or world best)

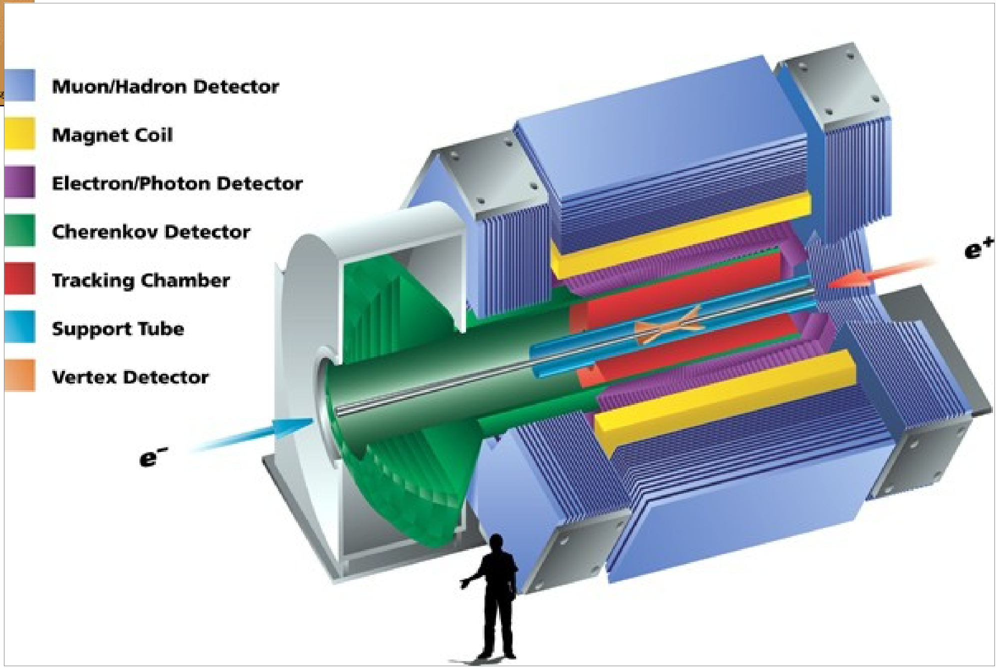
Additional Slides

The BaBar experiment



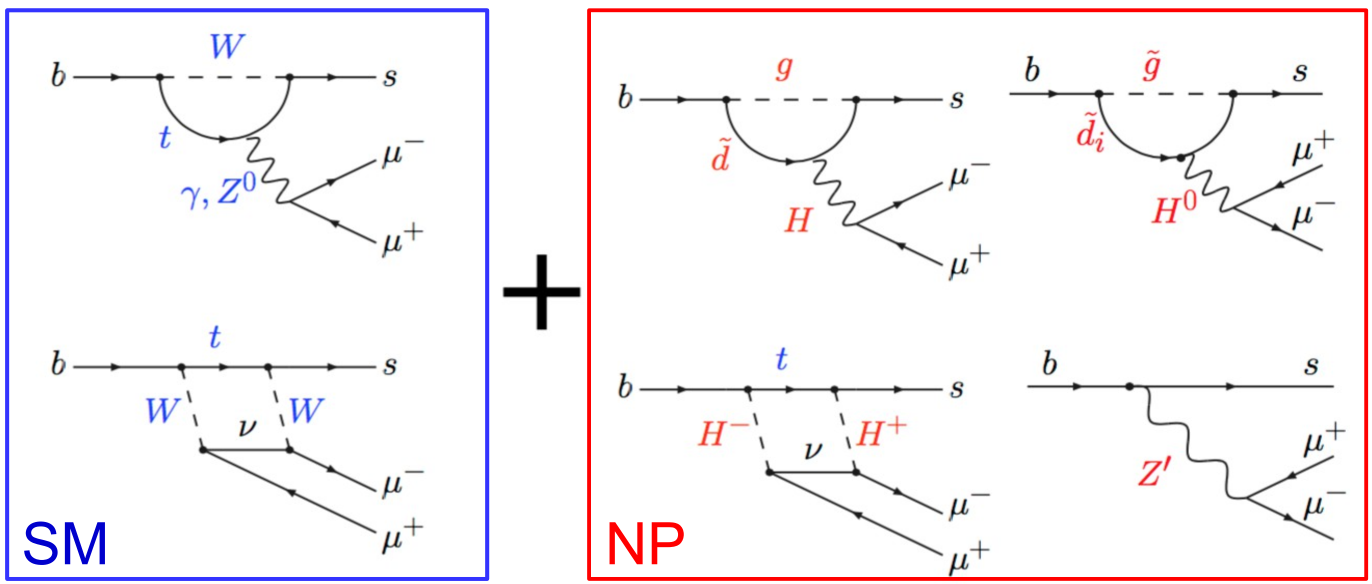
- BaBar at PEP-II asymmetric e^+-e^- collider at Stanford Linear Accelerator Center
- Operated (mainly) at Υ(4S) CM energy
- ≈500 fb^{-1} of e^+-e^- collisions recorded from 1999 to 2008

- Tracking: 40 layer drift chamber + 5 layer silicon vertex detector
- PID: π/K separation using dE/dx and quartz Ring Imaging Cherenkov Detector
- CsI(Tl) calorimeter for γ and e
- 1.5 T superconducting solenoid
- Muon detectors in the field flux return



$B \to K^{(*)} l^+ l^-$: motivation

- Search for new physics (NP) in intensity frontier → new "virtual" particles in loops
- $B \to K^{(*)} l^+ l^-$: flavor changing neutral current (FCNC) process, lowest order contribution from photon, Z penguins and W box in SM → theoretically clean
- New physics can enter at same order as SM → unambiguous



- Complementary to searches for pure leptonic decays (e.g. $B_s \to \mu^+\mu^-$) and lepton universality (e.g. $B(B \to D^* \mu \nu)/B(B \to D^* e\, \tau\, \nu)$)
- Significant deviations reported by various experiments

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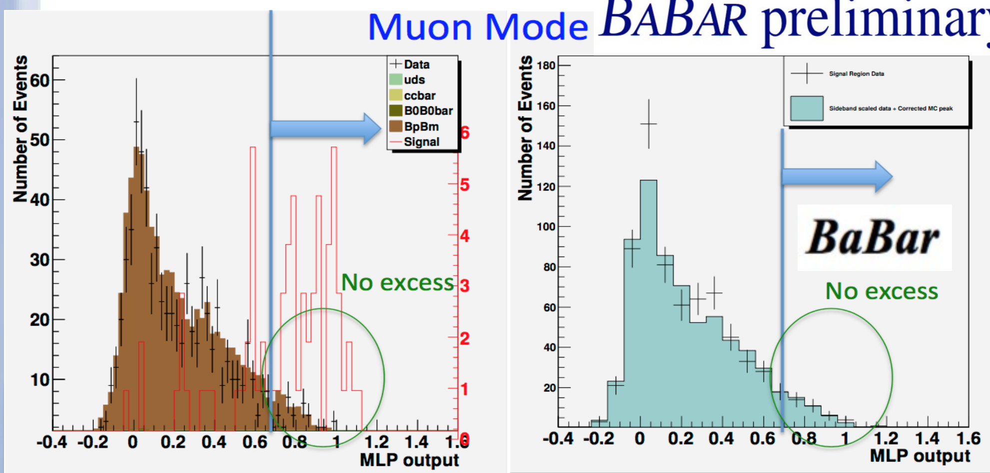
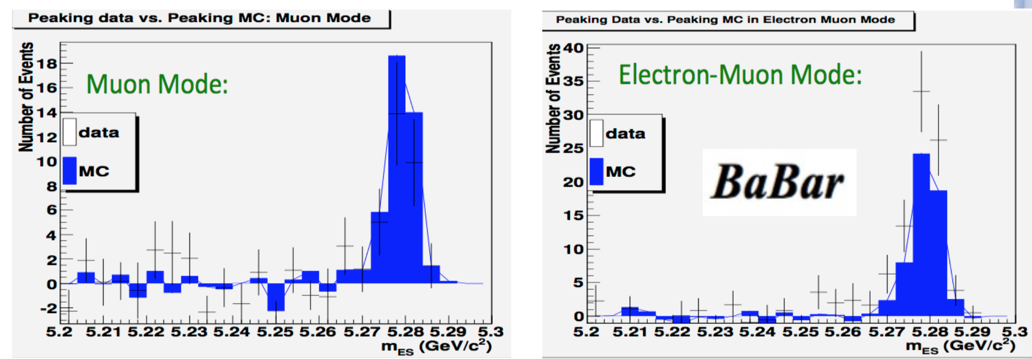
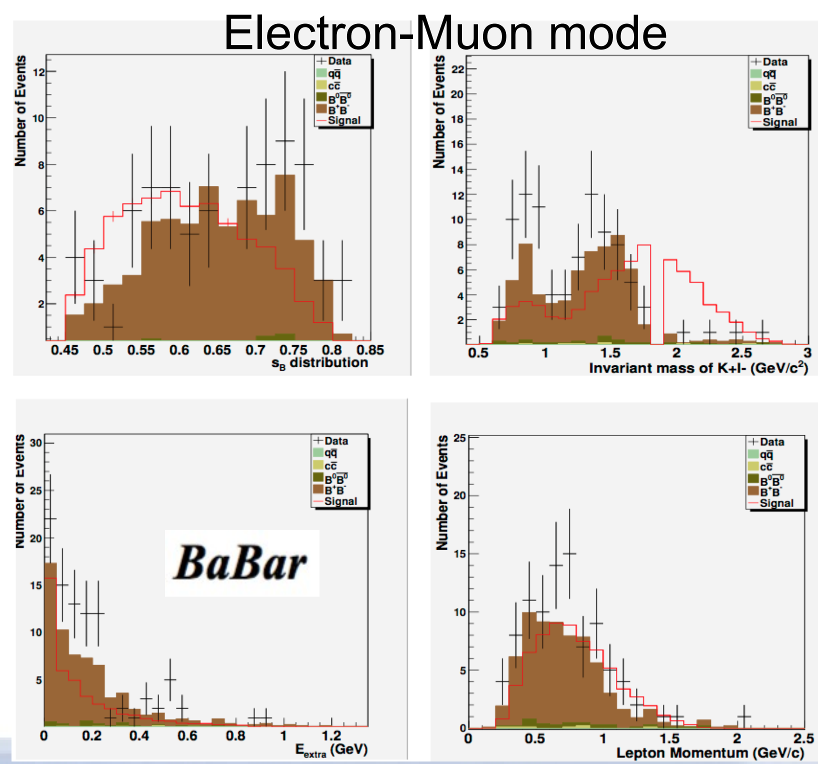
$B^+ \rightarrow K^+\tau^+\tau^-$: excess in $e\mu$ mode

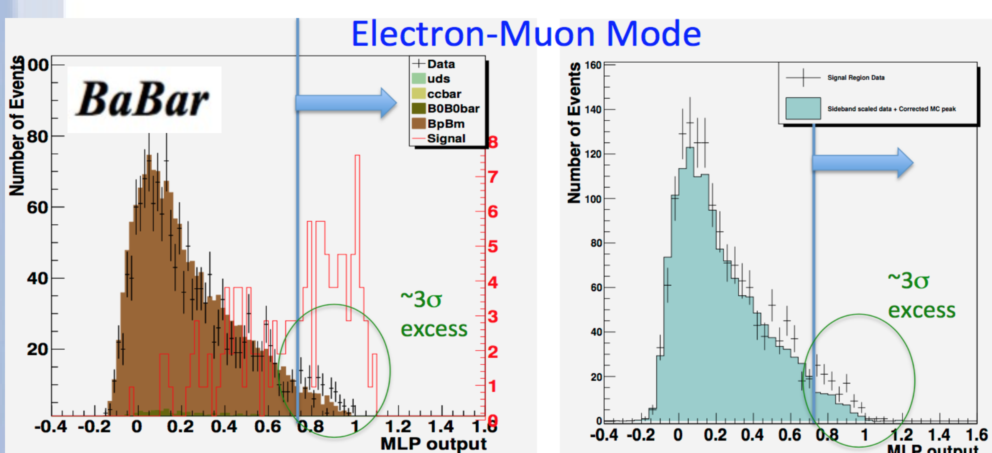
- 2.9σ excess in event yield observed in the mixed mode

BABAR preliminary









BABAR preliminary

$B \to K^{*}l^{+}l^{-}$: numerical angular results

F_L

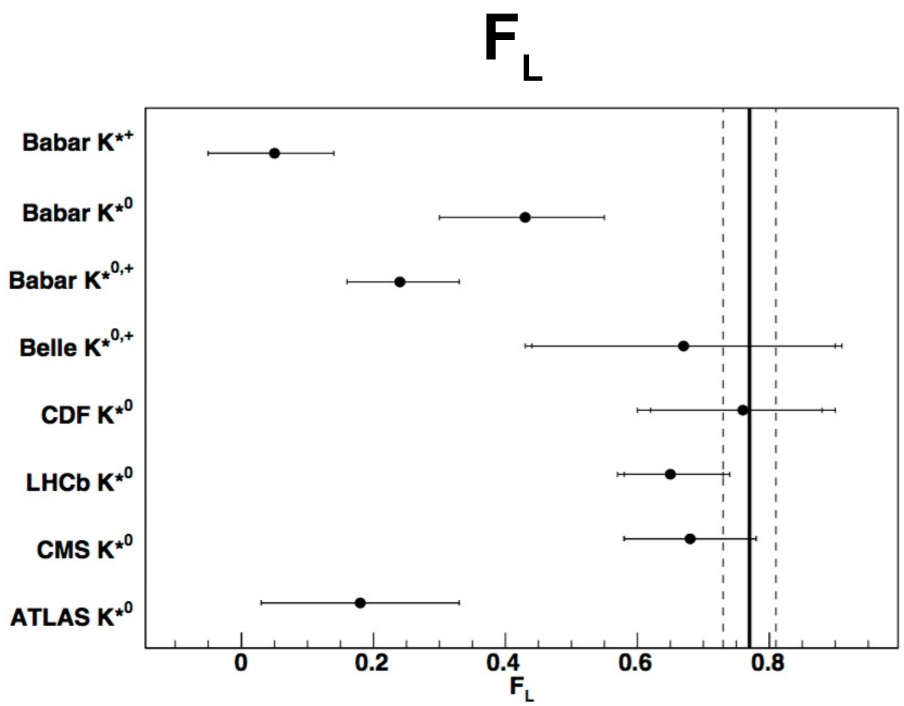
	$B^+ \to K^{*+}\ell^+\ell^-$	$B^0 \to K^{*0}\ell^+\ell^-$	$B \to K^*\ell^+\ell^-$
q_0^2	$+0.05^{+0.09}_{-0.10}{}^{+0.02}_{-0.10}$	$+0.43^{+0.12}_{-0.13}{}^{+0.02}_{-0.02}$	$+0.24^{+0.09}_{-0.08}{}^{+0.02}_{-0.02}$
q_1^2	$-0.02^{+0.18}_{-0.13}{}^{+0.09}_{-0.14}$	$+0.34^{+0.15}_{-0.10}{}^{+0.15}_{-0.02}$	$+0.29^{+0.09}_{-0.12}{}^{+0.13}_{-0.05}$
q_2^2	$-0.24^{+0.27}_{-0.39}{}^{+0.18}_{-0.10}$	$+0.18^{+0.16}_{-0.12}{}^{+0.02}_{-0.10}$	$+0.17^{+0.14}_{-0.15}{}^{+0.02}_{-0.02}$
q_3^2	$+0.15^{+0.14}_{-0.13}{}^{+0.05}_{-0.08}$	$+0.48^{+0.14}_{-0.16}{}^{+0.05}_{-0.05}$	$+0.30^{+0.12}_{-0.11}{}^{+0.05}_{-0.07}$
q_4^2	$+0.05^{+0.27}_{-0.16}{}^{+0.16}_{-0.15}$	$+0.45^{+0.09}_{-0.14}{}^{+0.06}_{-0.06}$	$+0.34^{+0.15}_{-0.10}{}^{+0.07}_{-0.10}$
q_5^2	$+0.72^{+0.20}_{-0.31}{}^{+0.10}_{-0.21}$	$+0.48^{+0.12}_{-0.12}{}^{+0.02}_{-0.11}$	$+0.53^{+0.10}_{-0.12}{}^{+0.07}_{-0.14}$

A_{FB}

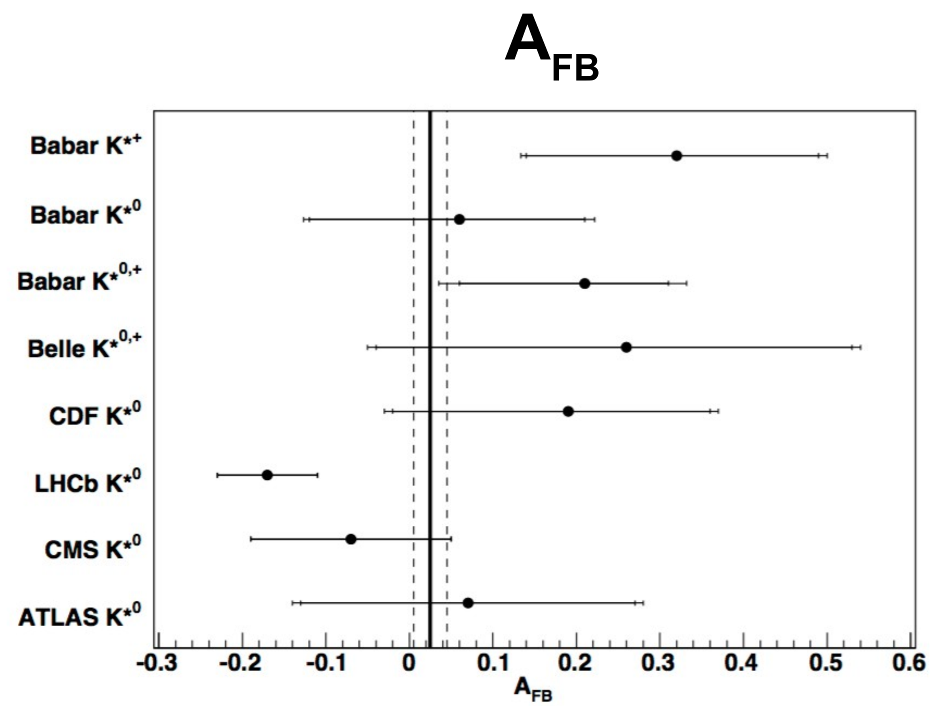
	$B^+ \to K^{*+}\ell^+\ell^-$	$B^0 \to K^{*0}\ell^+\ell^-$	$B \to K^*\ell^+\ell^-$
q_0^2	$+0.32^{+0.18}_{-0.18}{}^{+0.08}_{-0.05}$	$+0.06^{+0.15}_{-0.18}{}^{+0.06}_{-0.05}$	$+0.21^{+0.10}_{-0.15}{}^{+0.07}_{-0.09}$
q_1^2	$+0.44^{+0.20}_{-0.22}{}^{+0.13}_{-0.16}$	$-0.12^{+0.23}_{-0.21}{}^{+0.10}_{-0.21}$	$+0.10^{+0.16}_{-0.15}{}^{+0.08}_{-0.19}$
q_2^2	$+0.70^{+0.21}_{-0.38}{}^{+0.36}_{-0.49}$	$+0.33^{+0.21}_{-0.30}{}^{+0.12}_{-0.11}$	$+0.44^{+0.15}_{-0.18}{}^{+0.14}_{-0.11}$
q_3^2	$+0.11^{+0.22}_{-0.28}{}^{+0.08}_{-0.20}$	$+0.17^{+0.14}_{-0.16}{}^{+0.08}_{-0.08}$	$+0.15^{+0.14}_{-0.12}{}^{+0.08}_{-0.05}$
q_4^2	$+0.21^{+0.32}_{-0.33}{}^{+0.11}_{-0.24}$	$+0.40^{+0.12}_{-0.18}{}^{+0.17}_{-0.16}$	$+0.42^{+0.11}_{-0.17}{}^{+0.14}_{-0.13}$
q_5^2	$+0.40^{+0.26}_{-0.21}{}^{+0.18}_{-0.17}$	$+0.29^{+0.14}_{-0.17}{}^{+0.10}_{-0.10}$	$+0.29^{+0.07}_{-0.10}{}^{+0.10}_{-0.12}$

$B \to K^* l^+ l^-$: A_{FB} & F_L

$1.0 < q_0^2 < 6.0$ GeV



(a) F_L.



(b) $\mathcal{A}_{FB}$.

$B \to K^* l^+ l^-$: A_{FB} & F_L @LHCb

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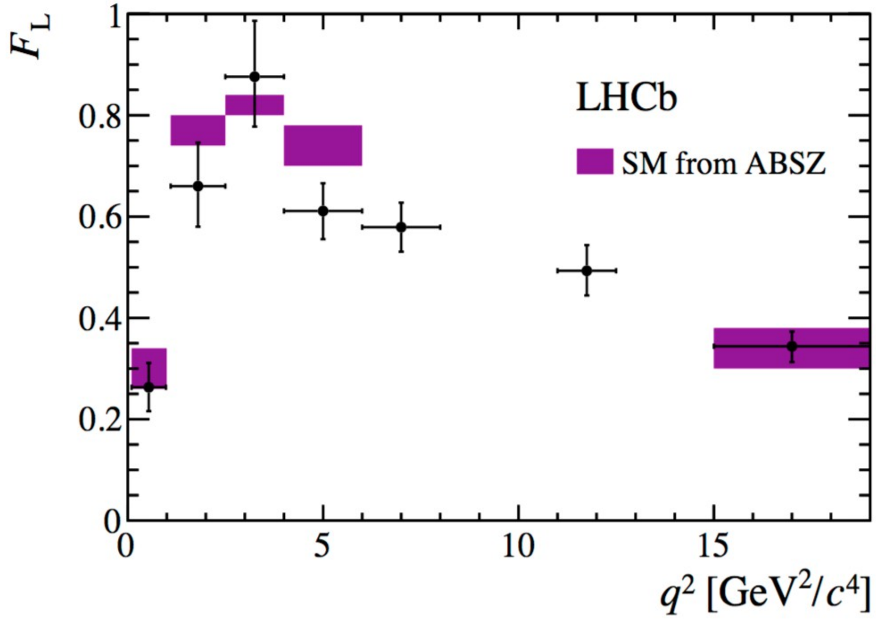
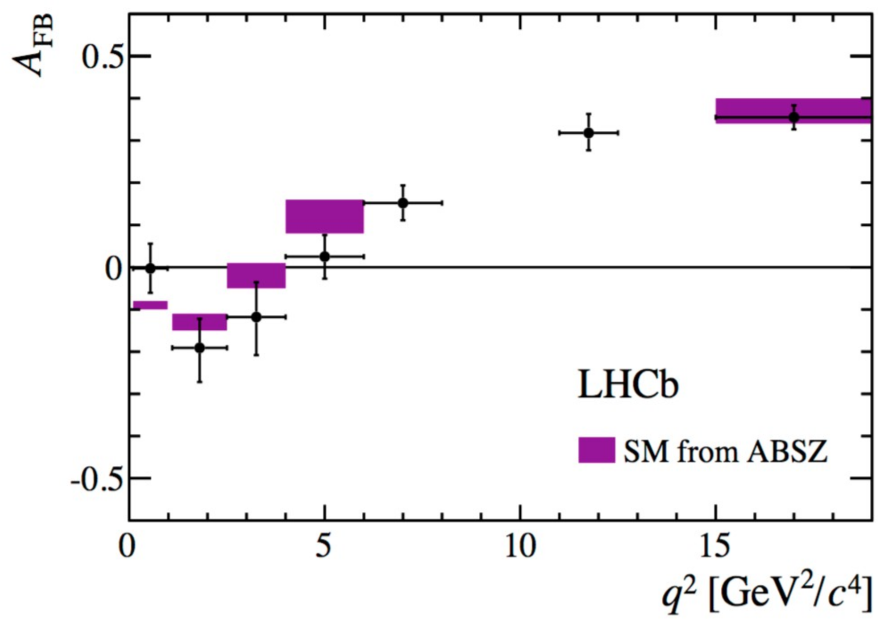
F_L

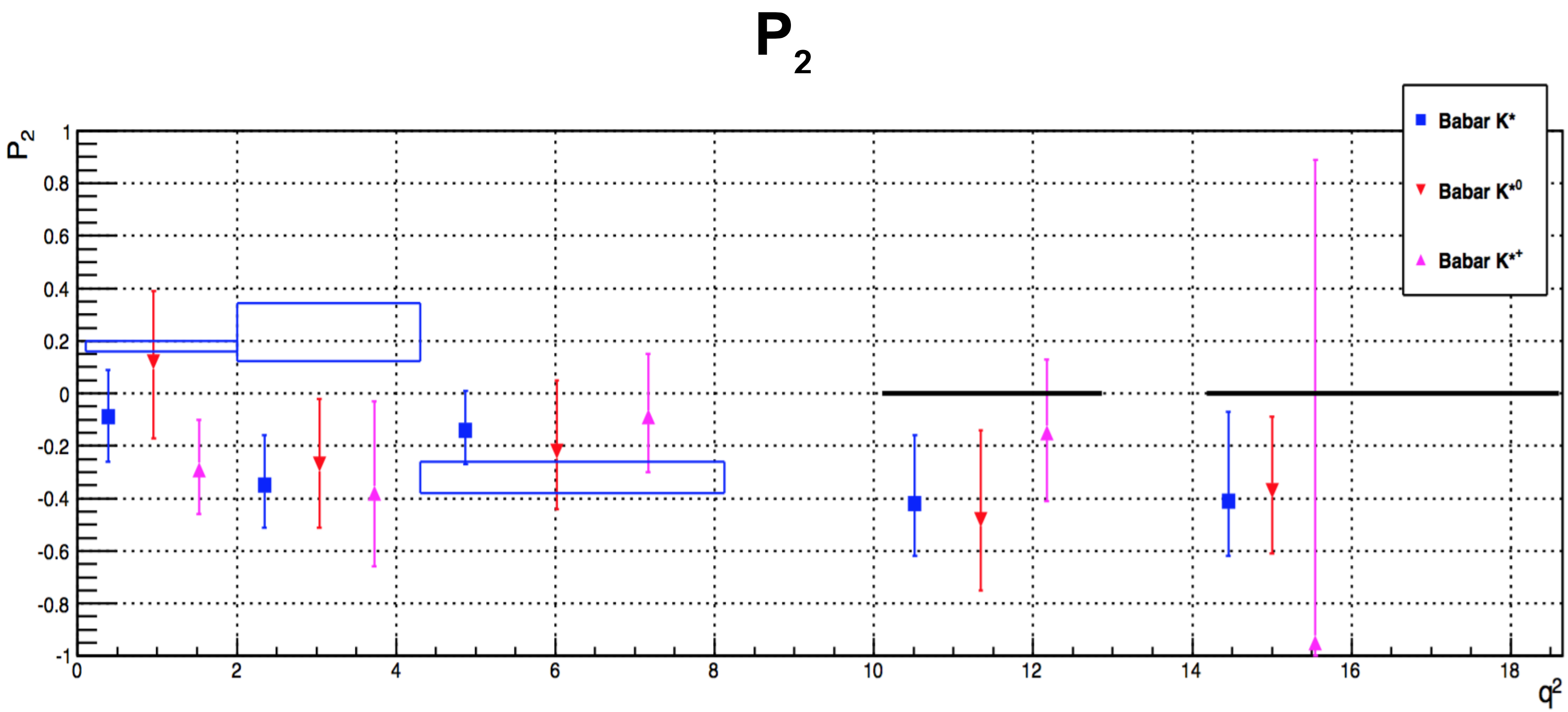


A_{FB}



$B \to K^{*}l^{+}l^{-}$: P_2

$P_2 = (\quad 2/3)\quad A_{FB}/(1\quad F_L) \rightarrow$ reduced theory uncertainty



$B \to K^{*}l^{+}l^{-}$: fit model

- Truth-matched signal pdfs:
  - Gaussian m_{ES}, relativistic Breit-Wigner $M_{K\pi}$ both from J/psi data
  - LH ratio and angular efficiency functions from signal MC
- Crossfeed signal pdfs:
  - m_{ES}, $M_{K\pi}$, LH ratio and angular shapes from MC, normalization relative to fit signal yield
- Physics backgrounds:
  - m_{ES}, $M_{K\pi}$, LH ratio fixed shapes and normalizations from MC
  - Several sources, all trivial except charmonium
- Random combinatoric background:
  - m_{ES} Argus, floated slope, fixed single-valued endpoint
  - $M_{K\pi}$ taken from LFV events selected identically to ee/mm samples
  - LH ratio from generic MC
  - Angular shapes from m_{ES} sideband and LFV events
- Hadronic mis-id backgrounds (di-muon final states only)
  - Fixed m_{ES}, $M_{K\pi}$, LH ratio and angular shapes plus