

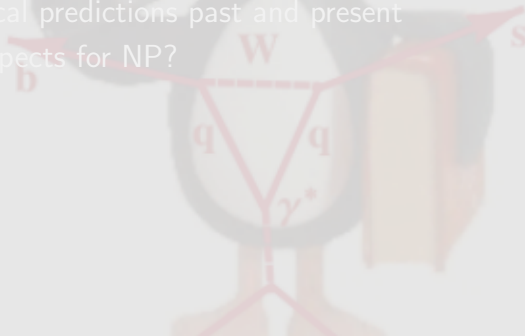
# The isospin asymmetry in $B \rightarrow K^* I^+ I^-$ decays: a theoretical perspective

Aoife Bharucha



Implications of LHCb measurements and future prospects,  
CERN, 16th April 2012

- **Soon to be updates experimental status**
- Tools for calculating non-factorizable effects
- Theoretical predictions past and present
- Any prospects for NP?



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## Definition

$$\frac{dA^I}{dq^2} = \frac{d\Gamma/dq^2(B^0 \rightarrow K^{*,0}I^+I^-) - d\Gamma/dq^2(B^\pm \rightarrow K^{*,\pm}I^+I^-)}{d\Gamma/dq^2(B^0 \rightarrow K^{*,0}I^+I^-) + d\Gamma/dq^2(B^\pm \rightarrow K^{*,\pm}I^+I^-)}$$

## Motivation

- Slight **experimental deviations** from theory predictions
- **Testing QCD factorisation** treatment of hard scattering effects
- **Probing NP** complementary to  $b \rightarrow s\gamma$

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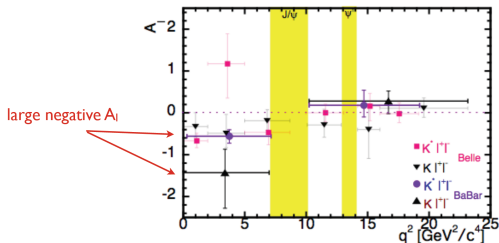
$$\frac{dA^I}{dq^2} = \frac{d\Gamma/dq^2(B^0 \rightarrow K^{*,0}l^+l^-) - d\Gamma/dq^2(B^\pm \rightarrow K^{*,\pm}l^+l^-)}{d\Gamma/dq^2(B^0 \rightarrow K^{*,0}l^+l^-) + d\Gamma/dq^2(B^\pm \rightarrow K^{*,\pm}l^+l^-)}$$

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## Isospin asymmetry results

- Babar (2009) measured a large value of  $A_1$  in the low- $q^2$  region:

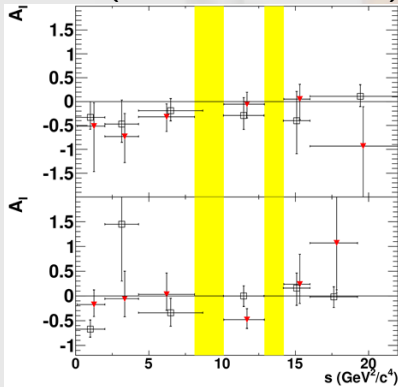


- Taking  $K^{*0}K^0$  and  $K^0K^0$  together, this is a  $3.9\sigma$  effect.
- Belle's results are consistent with SM (and also with BaBar results)
- Need more data to sort this out (updated Babar measurement coming within weeks)

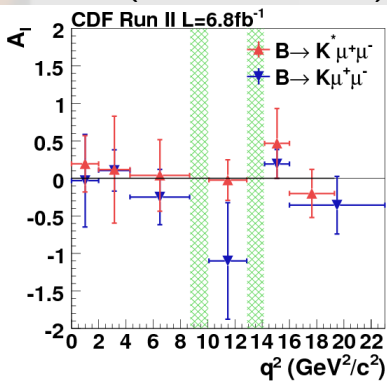


# Experimental status in brief

Babar (Moriond EW 2012)

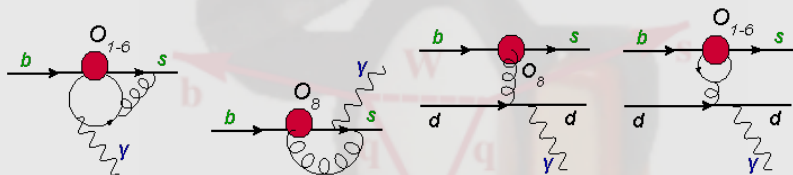


CDF (arXiv:1108.0695)



# Tools required for theoretical calculation

- **Form Factors:** describe hadronic matrix elements  $\langle B|J|K^* \rangle$
- **Wilson Coefficients:** parameterise hard physics, i.e. NP
- **QCDF:** provides a framework to calculate NLO effects



# Calculation of isospin asymmetry in QCDF

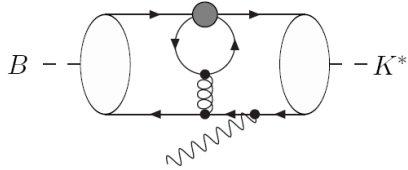
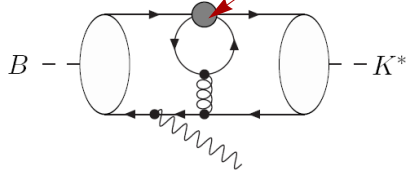
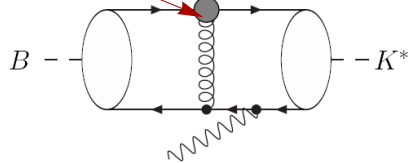
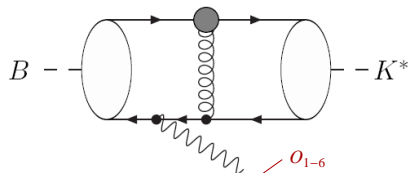
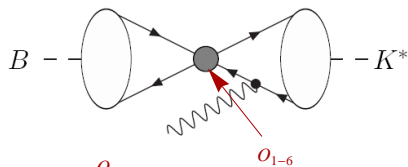
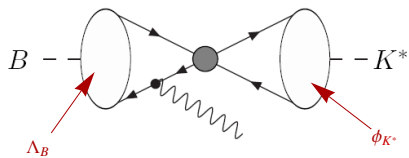
QCD factorisation required<sup>1</sup>, asymmetry vanishes in naïve factorisation

- **Two types of Diagrams:** weak annihilation and hard spectator scattering
- Require **Light-cone distribution amplitudes** of  $B/K^*$  mesons ( $\Lambda_B/\phi_K^*$ )
- Short distance physics described by **Wilson coefficients**  $C_{1-6,8}$

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<sup>1</sup>T. Feldmann and J. Matias, "Forward backward and isospin asymmetry for  $B \rightarrow K^* l^+ l^-$  decay in the standard model and in supersymmetry," JHEP **0301** (2003) 074 [hep-ph/0212158].

# Calculation of isospin asymmetry in QCDF



# Details of the calculation

- Calculation involves convolution of hard scattering amplitude with light-cone distribution amplitudes (DAs) of the  $B$  and  $K^*$  meson

$$\mathcal{T}_a^{(i)} = \phi_B \times T_a^{(i)} \times \phi_{a,K^*}$$

- At leading order only weak annihilation contributes, vanishes at zero  $q^2$  ( $\sim A_1(B \rightarrow K^* \gamma)$ ) but dominates at medium  $q^2$ , sensitive to  $C_4 + C_3/N_C$
- subleading effects in  $1/m_B$  dominate at low  $q^2$ , sensitive to  $C_6 + C_5/N_C$ , as found in  $B \rightarrow K^* \gamma^1$

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## Possible issues

- IR divergences in hard spectator scattering integral  $X_{\perp}$  involving  $O_8$  signal breakdown of QCDF at order  $1/m_B^2$ . Use cut-off,  $(1 + \rho e^{i\phi}) \int_0^{1-\Lambda_h/m_B} du X_{\perp}(u)$  for  $\rho$  in range 0 to 1 and  $\phi$ , 0 to  $2\pi$
- Work to order  $\alpha_s O_{1,8}$  and neglect  $\alpha_s O_{3-6}$ , therefore no  $\alpha_s$  corrections to weak annihilation
- Subleading contributions in  $1/m_B$  to amplitude for longitudinal photon polarisations not calculated, as require twist-3 contributions to the  $B$  meson DA
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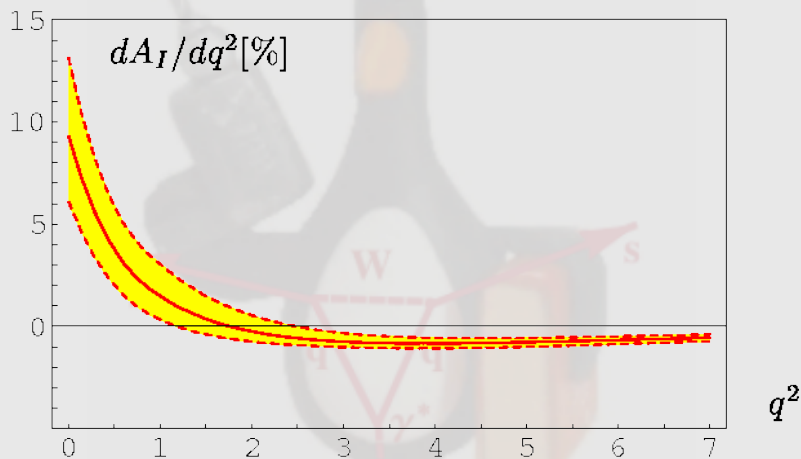
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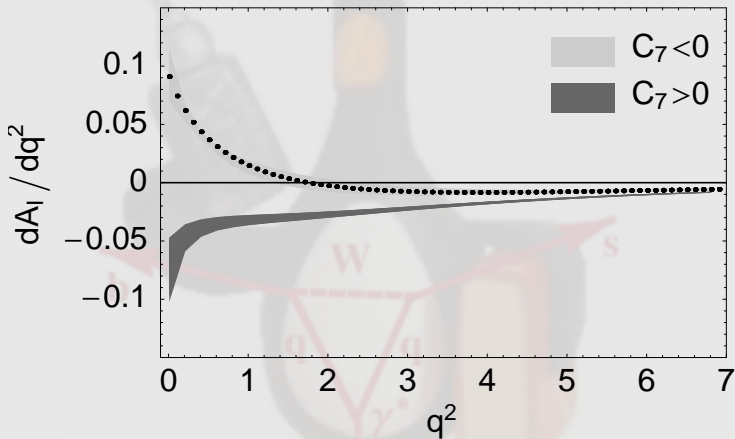
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# Results from Feldmann-Matias '02

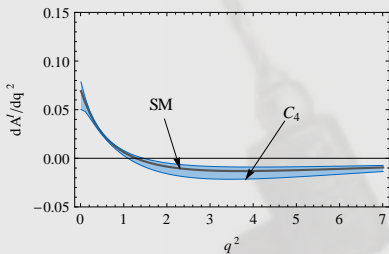


(Main uncertainties from  $\xi_{\perp,\parallel}$ ,  $\Lambda_B$ ,  $f_B$ ,  $X_{\perp}$ )

# Results from Feldmann-Matias '02



# Prospects for new physics?

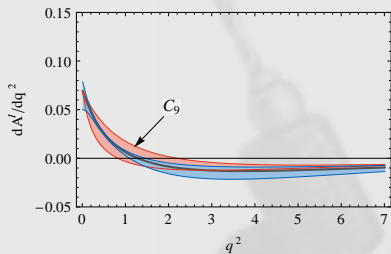


$A_1(B \rightarrow K^* \gamma)$  constrains  
 $C_6 + C_5/N_C$  and relative sign with  
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Exp:  $0.052 \pm 0.026$  (HFAG from  
Babar 09, Belle 04)

- $b \rightarrow s \gamma$  constrains  $C_7$  and  $C_7'$
- $C_{3-6}$  constrained by non-leptonic  $B$  decays<sup>1</sup>, life-time differences of  $B$  mesons and Kaon decays but deviations still allowed
- Can be generated in the MSSM when gluino-squark dominates and some models of extra dimensions
- To make conclusive statements would need a better understanding of the  $B$  meson and  $K^* \gamma$  LC wave functions

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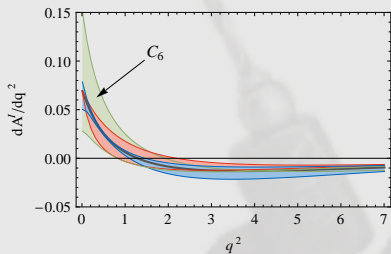
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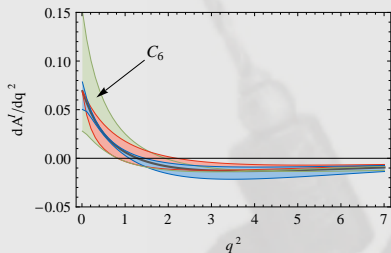


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- The experimental precision on the isospin asymmetry **measurement is rapidly improving**
- Theoretical results requiring **QCD factorisation** were calculated by Feldmann/Matias in 2002
- If a **large deviation from zero** was observed it would be **interesting for the MSSM and MFV**
- Still the theoretical calculations has **room for improvement** and advancements on the  **$B$  meson LCDA and  $K^*\gamma$  DA** would be welcome (also improved errors on  $f_B$  and  $\xi_{\perp/\parallel}$  from the Lattice)

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