# Exploring non-factorisable contributions to charmless B-decays

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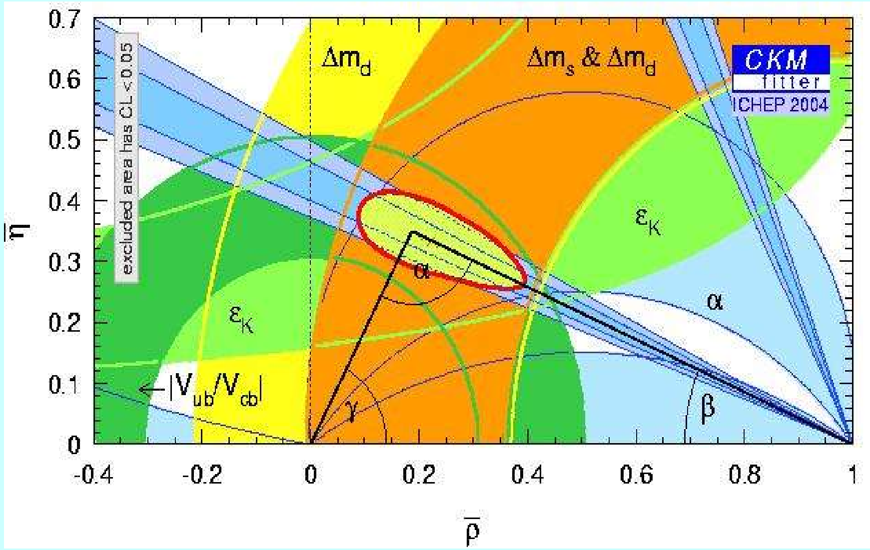
# Introduction and motivation

- B-factories are getting more and more data
- CKM angles getting better and better constrained
- However, some areas of the theory is not quite keeping up with the experimental improvements

There are still discrepencies over how to treat power-suppressed corrections to non-leptonic B-decays

$$B \rightarrow \pi\,\pi$$



# Introduction and motivation

Why do we want to do this?

- The $B \to \pi\pi$ system is well known experimentally

  (3 branching ratios, 2 CP asymmetries)

- Amplitudes are governed by isospin symmetry

  → All QCD parameters can be determined from experiment, as a function of $\beta, \gamma$

- We have analysed recent experimental data on $B \to \pi\pi$ decays
- Use QCD Factorisation to estimate the factorisable contributions.....

  .....and determine the level of non-factorisable, (power-suppressed) contributions needed to reconcile theory ~ experiment

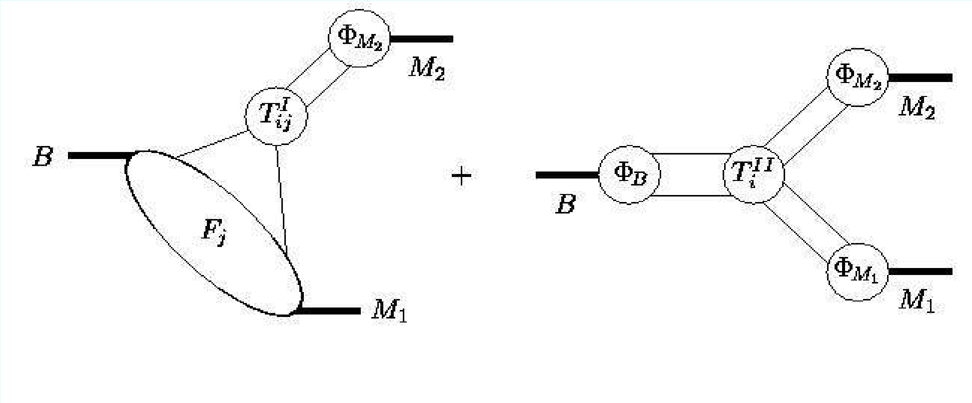
QCD Factorisation

# Theory framework – QCD Factorisation

$$\langle M_1 M_2 | Q_i | \bar{B} \rangle = \sum_{M_1, M_2} F_j^{B\to M_1} T_{ij}^{I} * f_{M_2} \Phi_{M_2} + T_i^{II} * f_B \Phi_B * f_{M_1} \Phi_{M_1} * f_{M_2} \Phi_{M_2} + O(1/m_b)$$

Beneke, Buchalla, Neubert, Sachrajda 1999

- Can systematically compute matrix elements
- Valid to 1-loop accuracy
- Calculated in heavy-quark limit $(m_b \to \infty)$ i.e, accurate to $O(1/m_b)$
  - Calculable hard-scattering kernals $T_{ij}^{I}, T_i^{II}$ known to $O(\alpha_s)$
  - Non-perturbative quantities $F^{B\to M}, \Phi_M$



# QCD Factorisation II – hadronic input

- Form Factors $F^{B \to \pi}$

  Results from lattice 0.23(2), 0.25(1) — hep-lat/0408019,0409116

  QCD Sum rules 0.26 — Ball, Zwicky hep-ph/0406232

- Light-cone distribution amplitudes of light mesons

  - describe low energy (hadronic) part of QCD process

$$\phi_\pi(u,\mu^2) = 6u(1-u)\left[1 + a_2(\mu^2)\, C_2^{3/2}(2u-1) + a_4(\mu^2)\, C_4^{3/2}(2u-1) + \dots\right]$$

Non-perturbative Gegenbauer moments

Orthogonal polynomials in quark momentum fraction, u

- We use a resummed model of the DA which includes effects from higher order Gegenbauer moments, described by physical parameter $\Delta$

  Asymptotic wavefunctions described as $\Delta = 1$ — Ball, Talbot hep-ph/0502115

# Non-factorisable contributions

We consider the power-supressed corrections to charmless, strangeless B-decays

- Wealth of data coming in from B-factories!
- Split the decay amplitudes into isospin components (2 complex numbers)
- Use QCDF approach to predict factorisable part of amplitude....

  .....then fit the NF part to compare with the data

$B \to \pi\,\pi$

- 3 branching ratios and 2 CP asymmetries --- data from BaBar, Belle and HFAG averages
- Input parameters: Form factor, Δ (for pion wavefunction)

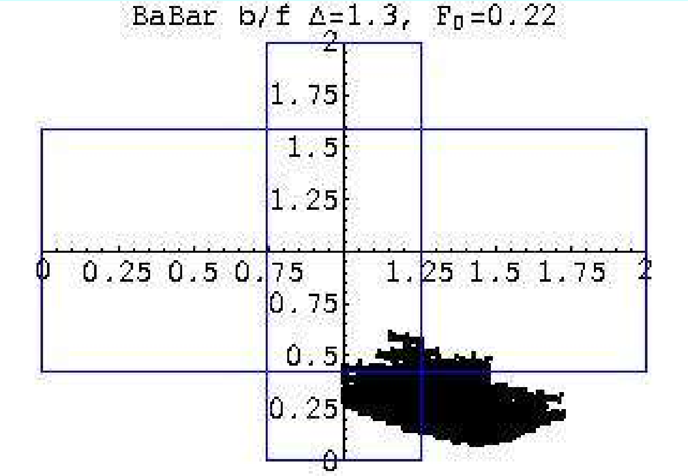
  CKM angles $\alpha, \beta, \gamma$ , $R_u = \sqrt{\bar{\rho}^2 + \bar{\eta}^2}$
- We find the "optimum" set of inputs to give best th/exp agreement

# Non-factorisable contributions to $B \rightarrow \pi\pi$

- "Naked" QCDF ⟶ $4\sigma$ deviation from experiment
- "Dressed" QCDF ⟶ Varying input paramters and add non-factorisable (NF) corrections

Expected 20% NF correction:

- Belle result does not agree within $3\sigma$
- BaBar results approach agreement to $2\sigma$




$\Gamma^{+-}_{TH} / \Gamma^{+-}_{\exp}$

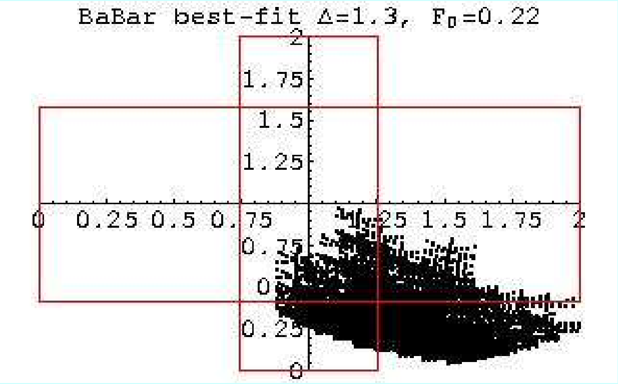
$\Gamma^{00}_{TH} / \Gamma^{00}_{\exp}$

# Non-factorisable contributions to $B \to \pi\pi$

- "Naked" QCDF ⟶ $4\sigma$ deviation from experiment
- "Dressed" QCDF ⟶ Varying input parameters and add non-factorisable (NF) corrections

<u>Limit 30% NF correction:</u>

- Belle result agree within $3\sigma$
- BaBar results agree to $2\sigma$

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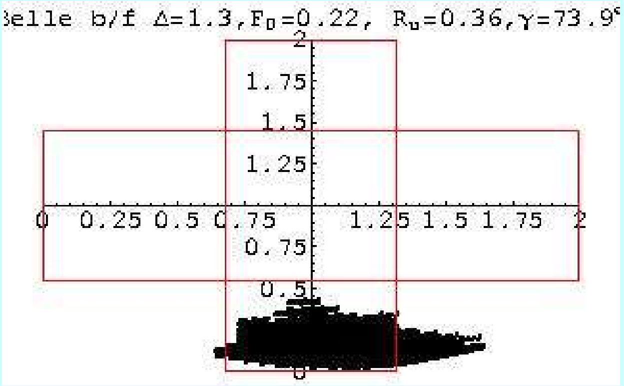


$\Gamma^{+-}_{TH} / \Gamma^{+-}_{exp}$

$\Gamma^{00}_{TH} / \Gamma^{00}_{exp}$

# Conclusions – what can we learn from this?

- QCD Factorisation cannot be blindly relied upon
- Predictions must take into account large non-factorisable corrections
- New experimental data may improve the theory~exp agreement.....

.....but if the central values remain, while the error improves, the discrepencies could be up to $8\sigma$ !

→ Breakdown of factorisation? Charming penguins? New physics?

This problem needs to be addressed soon!!

What does BaBar say?!

- Next step is application to $B \to K\pi$ :

Calculate leading terms in QCDF including SU(3) breaking
Use NF terms from $B \to \pi\pi$ (assuming SU(3) symmetry)
→ better agreement with data?

Stay Tuned!

P.Ball, G.W.Jones, ANT (to be published)