Charming Penguins Saga

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- **Episode I: *The penguin menace*** (1997) NPB501(1997)271
  - Lattice-inspired Wick contraction parameterization (*CE*, *DE*, *CP*, *DP*, ...)
  - Non-factorizable Cabibbo-enhanced contributions to $B \to K\pi$ decays
- **Episode II: *The neat hack of the clones*** (1998) NPB569(2000)3
  - Buras-Silvestrini RG-improved parameterization (E_1, E_2, P_1, P_2, ...)
- **Episode IV: *A new hope*** (1999) PRL83(1999)1914 (PRL74(1995)4388)
  - QCD (or pQCD) factorization holds in the $m_b \to \infty$ limit
- **Episode V: *Charming penguins strike back*** (2001) PLB515(2001)33
  - Charming penguins reinterpreted as $1/m_b$ corrections to factorization
- **Episode VI: *The return of factorization?*** (2002)
  - Are power-suppressed terms computable using factorization?

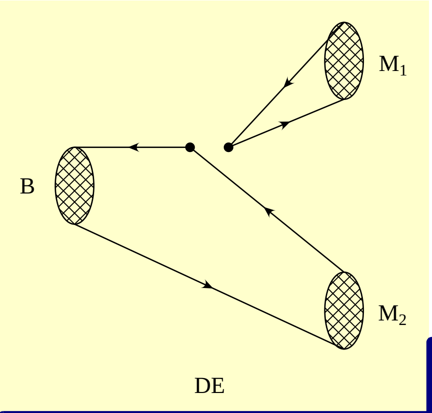
“Charming penguins” in $B \to K\pi$: Factorizable and non-factorizable contributions

It is instructive to start with an explicit example:

$$A(B_d \to K^+ \pi^-) = -V_{us} V_{ub}^* \times \{\boldsymbol{E_1}(s, u, u, B_d, K^+, \pi^-) - \boldsymbol{P_1^{GIM}}(s, u, B_d, K^+, \pi^-)\} + V_{ts} V_{tb}^* \times \boldsymbol{P_1}(s, u, B_d, K^+, \pi^-)$$

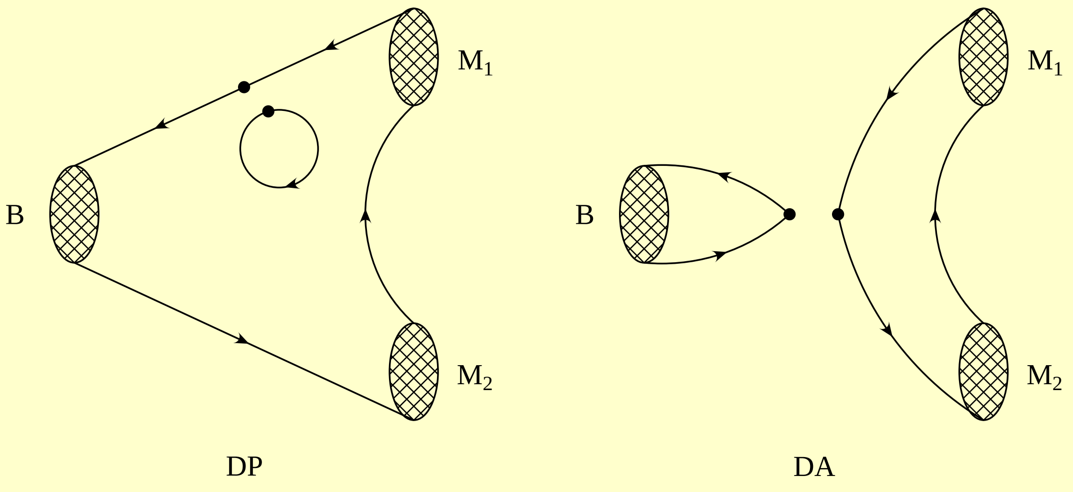
Called ***charming and GIM penguins*** in *MC et al.*, NPB501 (1997) 27
already discussed in *P. Colangelo et al.*, Z. Phys. C45 (1990) 575
see also *C. Isola et al.*, PRD64:014029,2001

N.B.: $V_{us} V_{ub}^* \sim \lambda^4, \; V_{ts} V_{tb}^* \sim \lambda^2$



Emission diagrams fully computed with QCD factorization

$$\boldsymbol{E_1}(s, u, u, B_d, K^+, \pi^-) \equiv C_1 \langle Q_1^u \rangle_{\mathbf{DE}} + C_2 \langle Q_2^u \rangle_{\mathbf{CE}} = a_1(K\pi) A_{\pi K}$$



The ***charming penguin*** parameter is split into a *factorizable contribution*, computed with QCD factorization, and a *genuine power-suppressed term* (denoted with a tilde), to be determined by a fit to the data

$$\boldsymbol{P_1}(s,u,B_d,K^+,\pi^-) \equiv C_1\langle Q_1^c\rangle_{\mathrm{CP}} + C_2\langle Q_2^c\rangle_{\mathrm{DP}} + \sum C_{2i-1}\langle Q_{2i-1}\rangle_{\mathrm{CE}} + C_{2i}\langle Q_{2i}\rangle_{\mathrm{DE}}$$
$$+\sum C_i(\langle Q_i\rangle_{\mathrm{CP}} + \langle Q_i\rangle_{\mathrm{DP}}) + \sum C_{2i-1}\langle Q_{2i-1}\rangle_{\mathrm{CA}} + C_{2i}\langle Q_{2i}\rangle_{\mathrm{DA}}$$
$$= a_4^c(K\pi)\, A_{\pi K} + \tilde{\boldsymbol{P}}_{\boldsymbol{1}}(s,u,B_d,K^+,\pi^-)$$

Similarly, the ***GIM penguin*** parameter can be split as:

$$\boldsymbol{P_1^{GIM}}(s,u,B_d,K^+,\pi^-) \equiv C_1(\langle Q_1^c\rangle_{\mathrm{CP}} - \langle Q_1^u\rangle_{\mathrm{CP}}) + C_2(\langle Q_2^c\rangle_{\mathrm{DP}} - \langle Q_2^u\rangle_{\mathrm{DP}})$$
$$= (a_4^c(K\pi) - a_4^u(K\pi))\, A_{\pi K} + \tilde{\boldsymbol{P}}_{\boldsymbol{1}}^{\boldsymbol{GIM}}(s,u,B_d,K^+,\pi^-)$$

Experimental measurement (Moriond '02)

γ from UTA + charming penguins

Fitted assuming flavor SU(2)

$BR(K^0\pi^0)\times 10^6$	$BR(K^+\pi^0)\times 10^6$
8.8 ± 2.2	11.5 ± 1.5
$8.7 \pm 0.7 +0.1 -0.2$	$10.6 \pm 0.9 +0.1 -0.2$
$BR(K^0\pi^+)\times 10^6$	$BR(K^+\pi^-)\times 10^6$
18.5 ± 2.2	18.6 ± 1.1
$19.8 \pm 1.4 +0.2 -0.0$	$18.5 \pm 1.0 -0.1 +0.1$

Predicted assuming flavor SU(3)

$BR(\pi^+\pi^-)\times 10^6$	$BR(\pi^+\pi^0)\times 10^6$
5.2 ± 0.6	5.3 ± 1.7
$9.3 \pm 3.4 +0.2 -0.3$	$5.1 \pm 2.0 +0.1 -0.0$
$BR(\pi^0\pi^0)\times 10^6$	
–	
$0.37 \pm 0.08 -0.0 +0.1$	

Main results

- agreement in $B \to K\pi$ channels
- predicted $BR(B_d \to \pi^+\pi^-)$ too large

CP asymmetries (within large errors):

$A(K^0\pi^0) \sim A(K^0\pi^-) \sim 0$, $A(\pi^+\pi^-) \sim \pm 0.4$

$A(K^-\pi^+) \sim A(K^-\pi^0) \sim \pm 0.15$

$$\tilde{P}_1 \equiv G_F f_\pi F_\pi(0)\, g\, |B_1|\, e^{i\phi_1}$$

$$|B_1| = 0.12 \pm 0.02 \qquad \phi_1 = (185 \pm 73 \pm 5)^\circ$$

Natural size of Λ/m_b corrections ~ 0.1-0.2

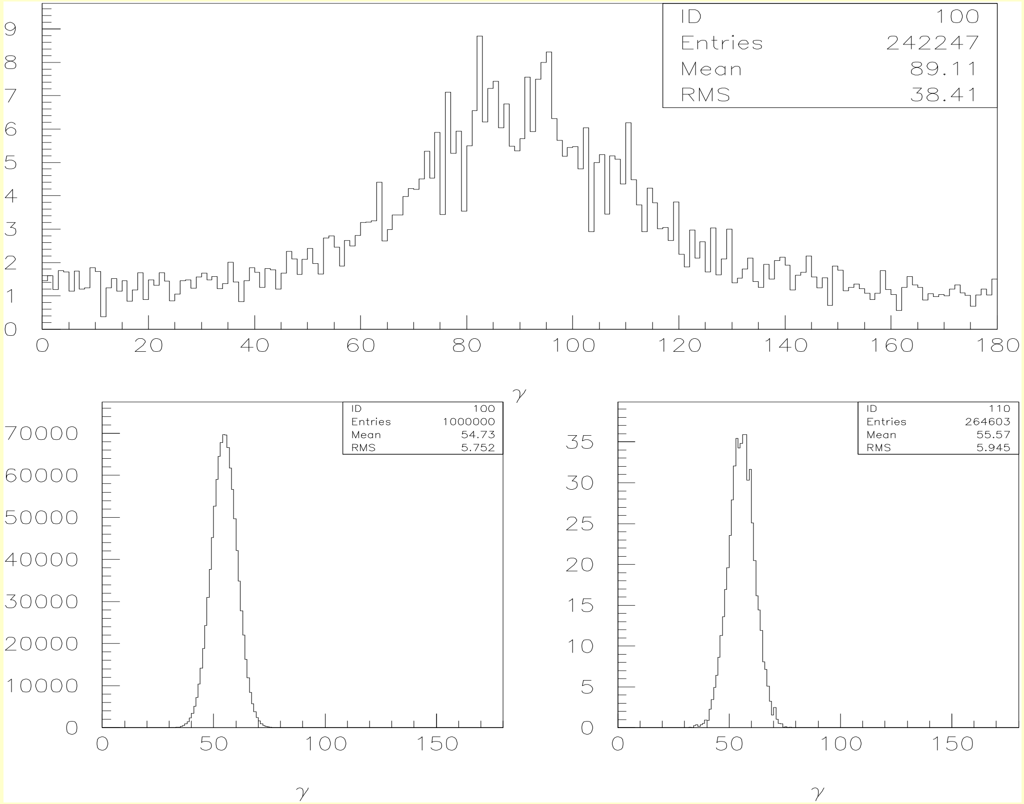
Few remarks on the results

- ✗ charming penguins are the power-suppressed corrections needed to reproduce the $B \to K\pi$ BRs: no more, no less.
- ✗ CP asymmetries are predicted with large errors. However vanishing values of A($B \to K^-\pi^+$) and A($B \to K^-\pi^0$) are not easily accomodated
- ✗ factorization+charming penguin predict a value of BR($B_d \to \pi^+\pi^-$) too large. However:
  - ◆ charming penguins are not Cabibbo-enhanced in $B \to \pi\pi$ modes
  - ◆ many other missing power-suppressed terms (e.g. GIM penguins)
- ✗ BR($B_d \to \pi^+\pi^-$) wants large power corrections. Otherwise it constrains the values of the input parameters (e.g. small form factors, large γ, ...)
- ✗ large Λ/m_b terms in $B \to \pi\pi$ modes may enhance BR($B_d \to \pi^0\pi^0$) up to few $\times\, 10^{-6}$

Information on γ are hindered by uncertainties on the phenomenological hadronic parameters

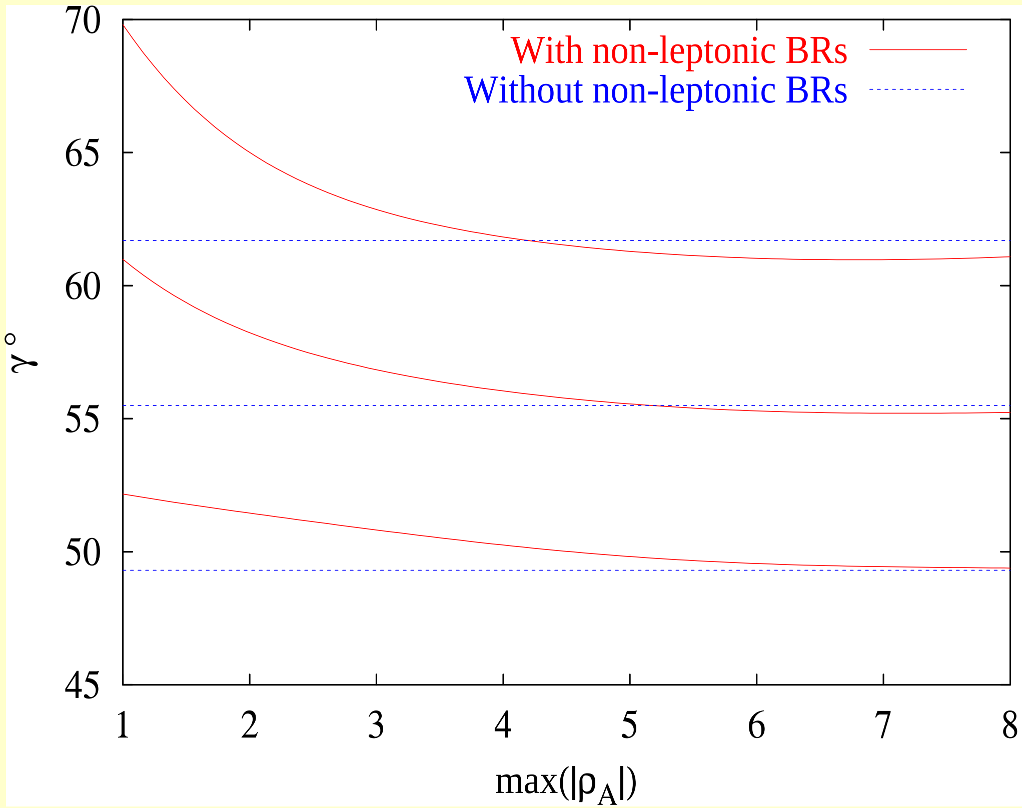
Fitting $K\pi, \pi\pi$ with *charming penguins* + γ :

- ✗ poor determination of γ (preferred γ ~ 90°)
- ✗ negligible effect on the penguin parameters
- ✗ negligible effect on the UTA fit



Using BBNS approach to $1/m_b$ terms:

- ✗ $|\rho_A| < 1$: γ larger than the UTA fit
- ✗ $|\rho_A| \geq 3$: γ unchanged (data prefer $|\rho_A| \sim 3$)



The “charming penguins” saga continues...

“Charming penguins” are a tool to study the effect of power-suppressed corrections based on:

- a complete parameterization
- dynamical assumptions to be checked on data

useful to check more specific approaches

Charming penguin parameter has been successfully extracted from $B \to K\pi$ data. More data are needed to check the consistency of the phenomenological picture and make predictions. For example:

- investigate further Λ/m_b terms in $B \to \pi\pi$ modes
- look for charming penguins effects in $B \to PV$ with transversely polarized vectors (vanishing in the factorization limit)

In any case: ***use the data, Luke!***