$B \to K^{(*)}\pi$ decays: the playground for models of hadronic effects in B decays

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All you are going to see is preliminary
papers in preparation

Outline

- The parameterization in terms of RG invariant quantities
- The data: how the Dalitz plot analyses give us enough data to fit the theory
- The results
- The challenge for the models

$B \rightarrow K^{*}\pi$

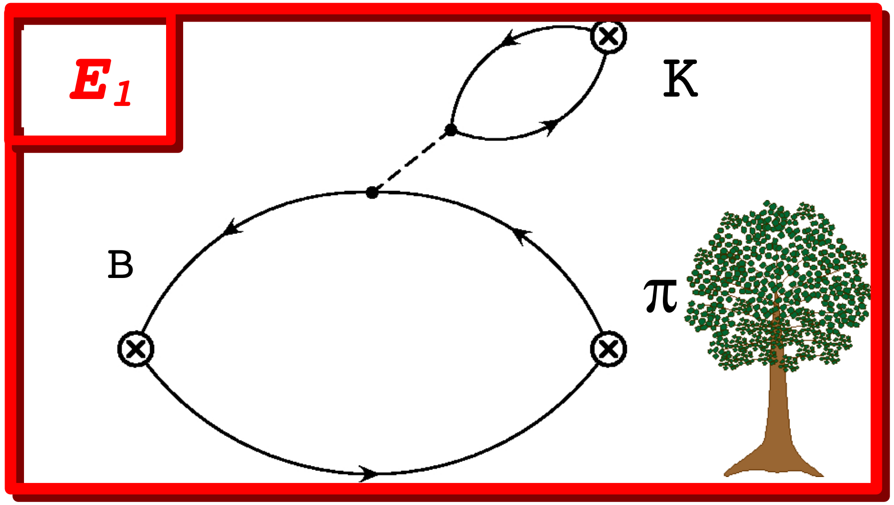
- The problem: less experimental observables
- Theory assumption to compensate it
- Results
- How does the Kp CP asymmetry puzzle arises

$B \rightarrow K\pi$

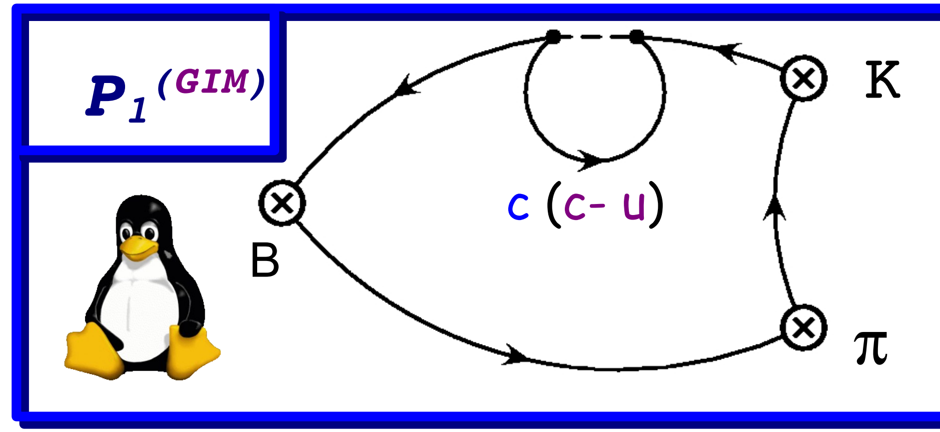
- Conclusions

The RGE Parameters

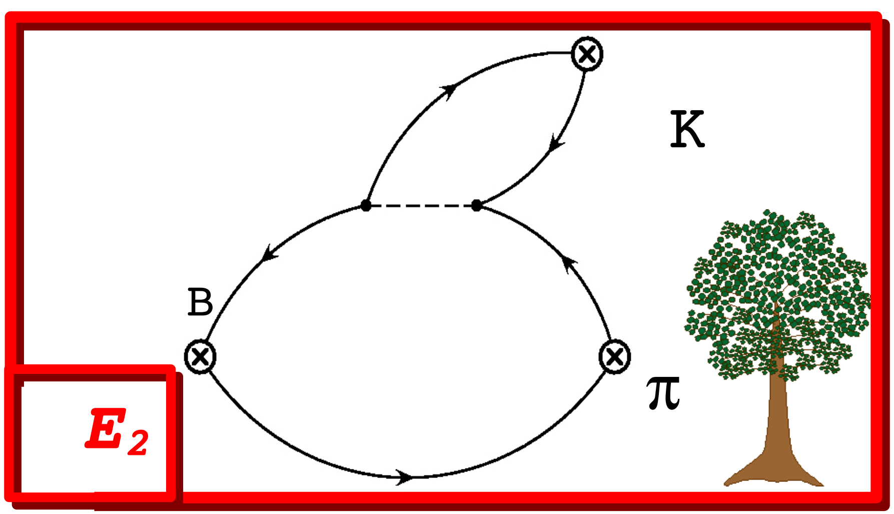
Disconnected emission



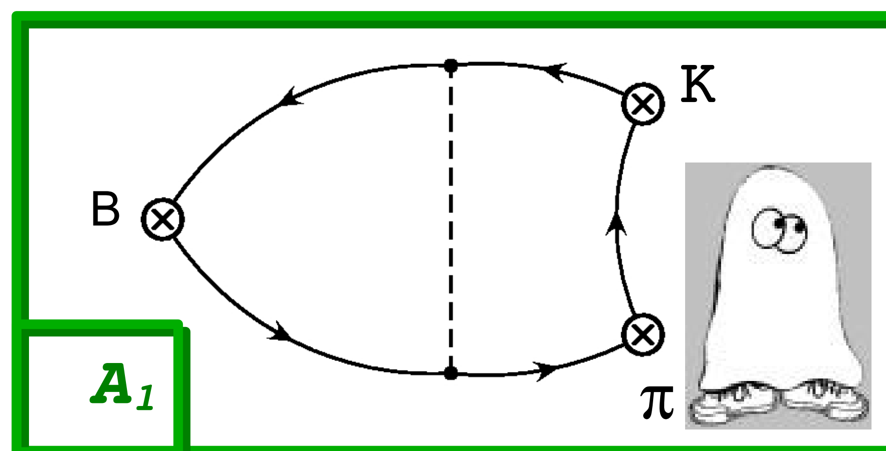
Charming and
GIM penguins(c-u)



Connected emission



Connected Annihilation



The decay Amplitudes

Fit the CKM matrix to the SM values

12 real unknowns -1 strong phase to fix

$$A(B^+ \to K^{(*)0}\pi^+) = -V_{ts}V_{tb}^* \{\tilde{P}_1 + \tilde{P}_3\}/2 + V_{us}V_{ub}^* \{\tilde{A}_1\}$$

$$\sqrt{2}\,A(B^+ \to K^{(*)+}\pi^0) = V_{ts}V_{tb}^* \{\tilde{P}_1\} - V_{us}V_{ub}^* \{E_1 + \tilde{E}_2 + \tilde{A}_1\}$$

$$A(B^+ \to K^{(*)+}\pi^-) = V_{ts}V_{tb}^* \{\tilde{P}_2\} - V_{us}V_{ub}^* \{E_1\}$$

$$\sqrt{2}\,A(B^0 \to K^{(*)0}\pi^0) = -V_{ts}V_{tb}^* \{\tilde{P}_3\} - V_{us}V_{ub}^* \{\tilde{E}_2\}$$

$$\tilde{E}_2 = E_2 - P_1^{GIM}$$

$$\tilde{A}_1 = A_1 - P_1^{GIM}$$

$$\tilde{P}_1 = P_1 + \Delta P_2$$

$$\tilde{P}_2 = P_1 + \Delta P_1$$

$$\tilde{P}_3 = P_1 - \Delta P_2$$

ΔP_2 and ΔP_2 are EW penguin corrections

The Experimental Inputs in $K^{(*)}\pi$

15 observables – 2 (twice the same measurements) -2 (isospin relation) =
11 independent constraints.
All the hadronic parameters can be determined

$K_s\pi^+\pi^-$ Dalitz Plot: $|A(B^0\to K^{*+}\pi^-)|$, $|A(\bar{B}^0\to K^{*-}\pi^+)|$ and relative phase

$K^+\pi^-\pi^0$ Dalitz Plot: $|A(B^0\to K^{*0}\pi^0)|$, $|A(B^0\to K^{*+}\pi^-)|$ and relative phase

$K^-\pi^+\pi^0$ Dalitz Plot: $|A(\bar{B}^0\to \bar{K}^{*0}\pi^0)|$, $|A(\bar{B}^0\to K^{*-}\pi^+)|$ and relative phase

$K_s\pi^+\pi^0$ Dalitz Plot: $|A(B^+\to K^{*+}\pi^0)|$, $|A(B^+\to K^{*0}\pi^+)|$ and relative phase

$K_s\pi^-\pi^0$ Dalitz Plot: $|A(B^-\to K^{*-}\pi^0)|$, $|A(B^-\to \bar{K}^{*0}\pi^-)|$ and relative phase

Not measured yet.

We replace it with the 2-body measurements of

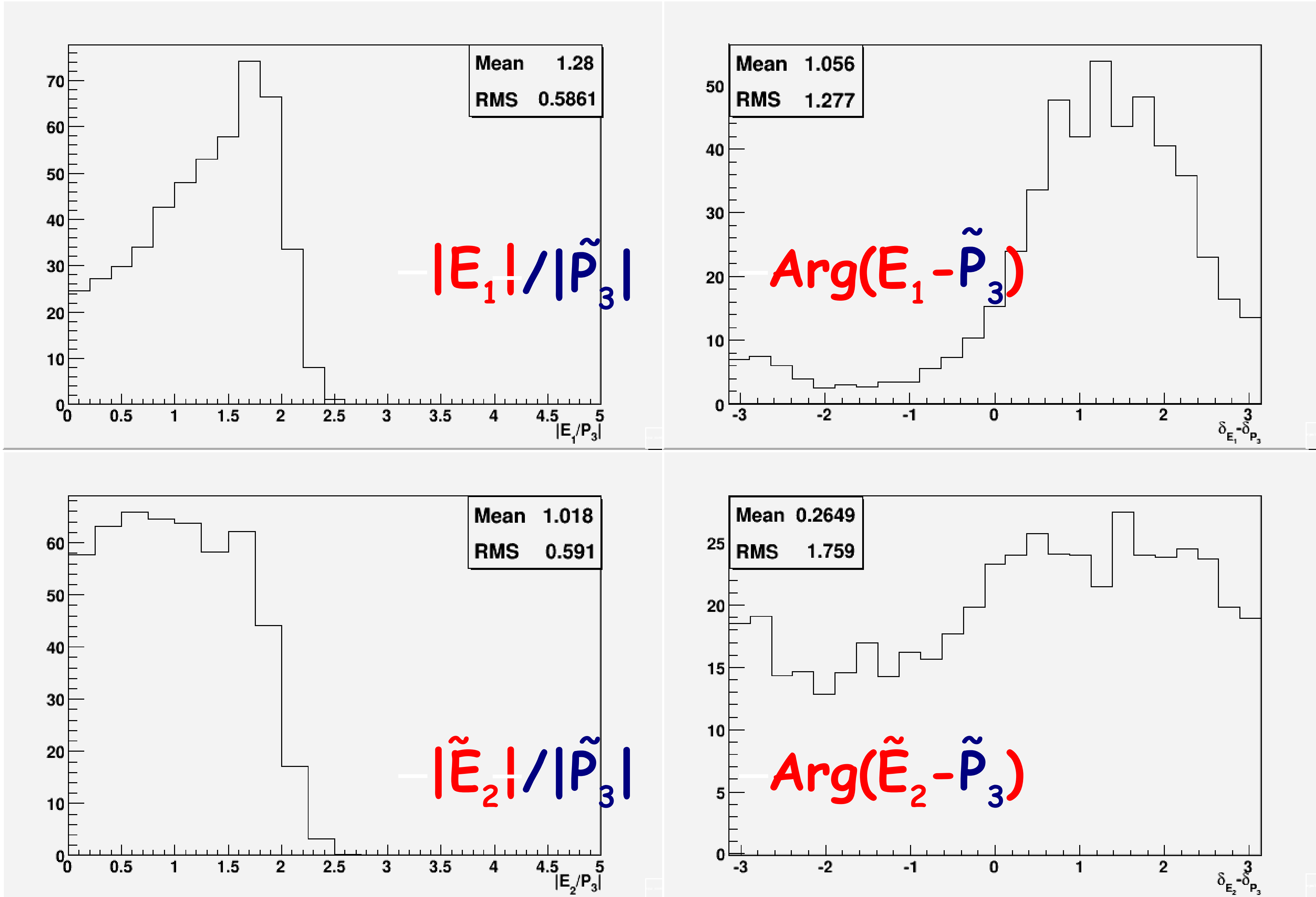
$BR(B\to K^*\pi^0)$ $ACP((B\to K^*\pi^0))$

$BR(B\to K^{*0}\pi)$ $ACP(B\to K^{*0}\pi)$

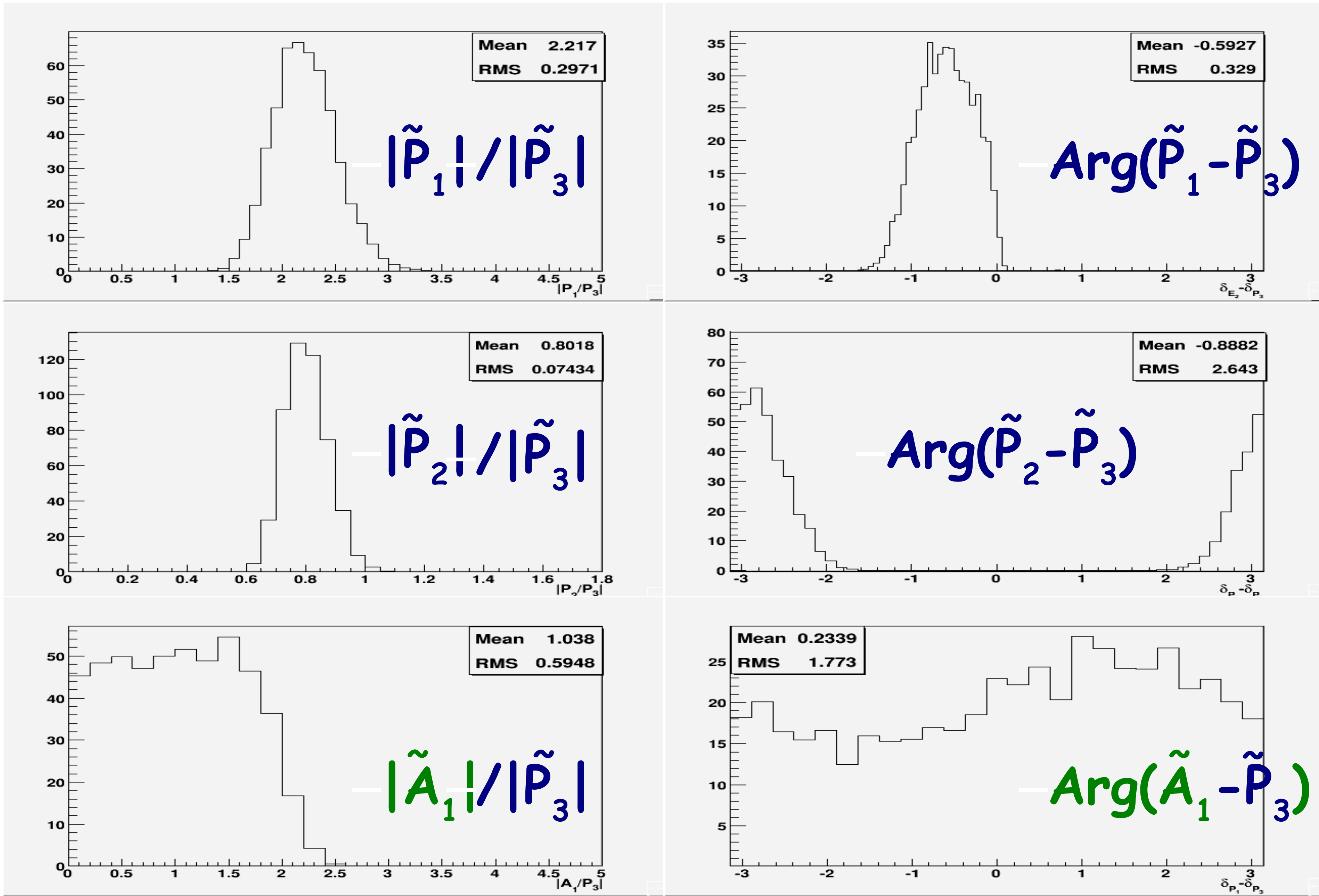
Still 11 independent constraints

Not possible in $K\pi$: we are missing the direct measurement of the interference effects

Fit Results $K^{(*)}\pi$ (I)



Fit Results $K^{(*)}\pi$ (II)



Theory information to compensate the lack of a Kπ Dalitz Plot equivalent

We compute the amplitudes in QCD factorization

$$E_1^{\mathrm{F}} \;=\; A_{\pi K}\left(-\alpha_1 - \alpha_4^u + \alpha_4^c - \alpha_{4,EW}^u + \alpha_{4,EW}^c\right)$$

We allow for the presence of $O(\Lambda_{QCD}/m_b)$ corrections

$$\begin{aligned}
E_1 &= E_1^{\mathrm{F}} + F\, r(E_1)e^{i\delta(E_1)}\,,\\
E_2 &= E_2^{\mathrm{F}} + F\, r(E_2)e^{i\delta(E_2)}\,,\\
A &= A^{\mathrm{F}} + F\, r(A)e^{i\delta(A)}\,,\\
P &= P^{\mathrm{F}} + F\, r(P)e^{i\delta(P)}\,,\\
\Delta P_1 &= \Delta P_1^{\mathrm{F}} + F\,\alpha_{\mathrm{em}}\, r(\Delta P_1)e^{i\delta(\Delta P_1)}\,,\\
\Delta P_2 &= \Delta P_2^{\mathrm{F}} + F\,\alpha_{\mathrm{em}}\, r(\Delta P_2)e^{i\delta(\Delta P_2)}\,,
\end{aligned}$$

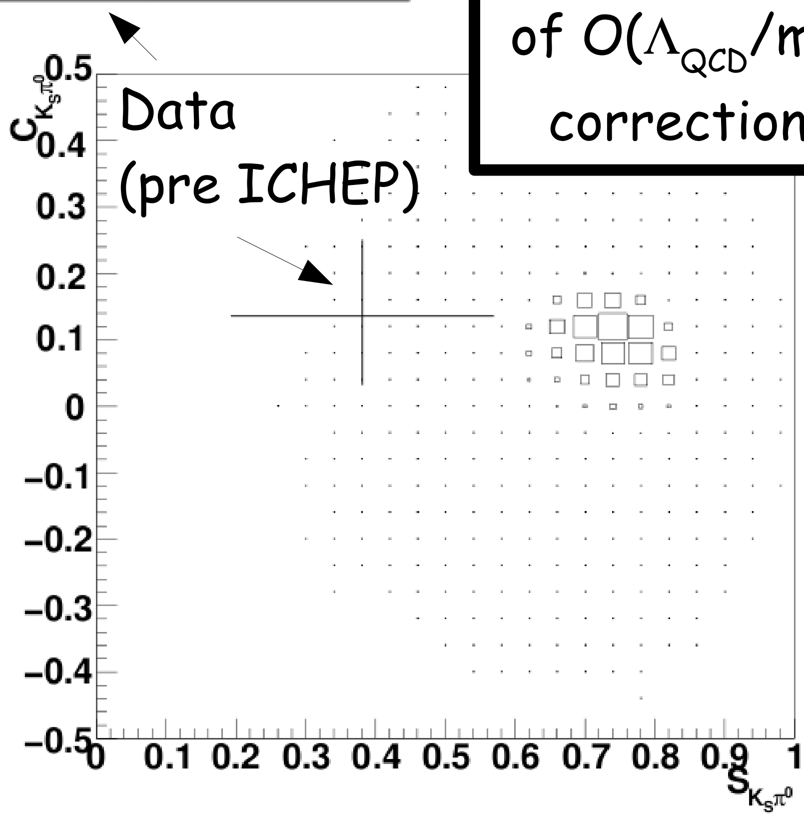
We enforce the $O(\Lambda_{QCD}/m_b)$ power expansion (used for the factorization formula in the $m_b \to \infty$ limit) as a limit on the allowed range of the hadronic unknowns ($[0, 0.5] \times E_1^F$)

Fit Results Kπ

The experimental measurements

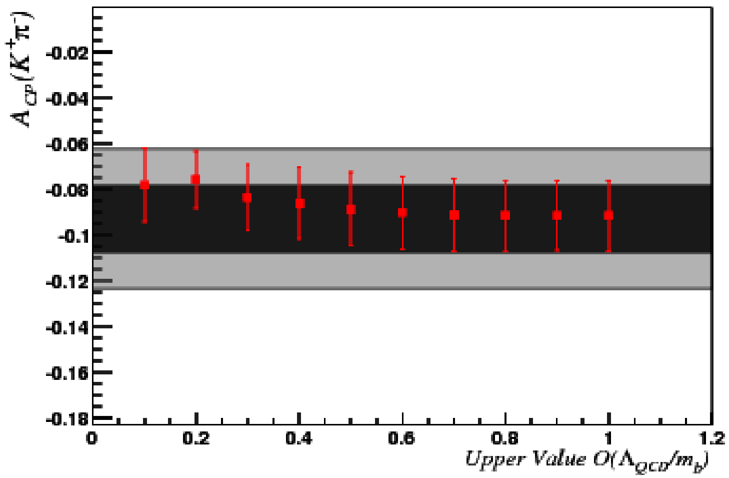
Decay Mode	$\mathrm{BR}^{\mathrm{exp}} \times 10^6$	$\mathcal{A}_{\mathrm{CP}}^{\mathrm{exp}} = -C$	S
$K^+\pi^-$	19.4 ± 0.6	-0.097 ± 0.012	–
$K^+\pi^0$	12.9 ± 0.6	0.050 ± 0.025	–
$K^0\pi^+$	23.1 ± 1.0	0.009 ± 0.025	–
$K^0\pi^0$	9.9 ± 0.6	-0.14 ± 0.11	0.38 ± 0.19

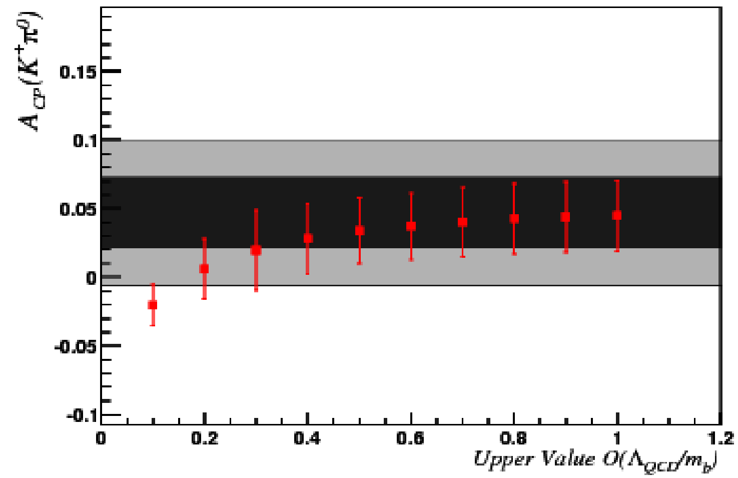
	global fit	fit prediction
$\mathrm{BR}(K^+\pi^-) \times 10^6$	19.6 ± 0.5	20.1 ± 1.0
$\mathrm{BR}(K^+\pi^0) \times 10^6$	12.7 ± 0.5	12.4 ± 0.7
$\mathrm{BR}(K^0\pi^+) \times 10^6$	23.7 ± 0.8	24.6 ± 1.2
$\mathrm{BR}(K^0\pi^0) \times 10^6$	9.2 ± 0.4	8.6 ± 0.6
$\mathcal{A}_{\mathrm{CP}}(K^+\pi^-)$	-0.094 ± 0.012	0.01 ± 0.07
$\mathcal{A}_{\mathrm{CP}}(K^+\pi^0)$	0.041 ± 0.023	-0.03 ± 0.06
$\mathcal{A}_{\mathrm{CP}}(K^0\pi^+)$	0.014 ± 0.020	0.04 ± 0.05
$C(K_S\pi^0)$	0.11 ± 0.03	0.10 ± 0.04
$S(K_S\pi^0)$	0.72 ± 0.04	0.74 ± 0.04
ΔA_{CP}	0.135 ± 0.025	0.060 ± 0.068



SM prediction in presence of $O(\Lambda_{QCD}/m_b)$ corrections

How does the Asymmetry puzzle arise?





Within this exercise, the perturbative limit is recovered sending to 0 the upper value of the allowed range for the corrections

When the $O(\Lambda_{QCD}/m_b)$ corrections are allowed it is possible to describe the experimental data

When the $O(\Lambda_{QCD}/m_b)$ corrections are switched off, the two asymmetries are forced to be opposite-sign (unlike what measured)

This is a strong indication of the fact that $O(\Lambda_{QCD}/m_b)$ corrections have to be taken into account

Conclusions

$K^*\pi$ decays give us a unique opportunity to determine ALL the hadronic parameters directly from data (unlike Kpi decays), thanks to the richness of the Dalitz Plot analyses

By adding a moderate model-dependence (namely implementing the $O(\Lambda_{QCD}/m_b)$ expansion) a similar exercise can be performed for $BK\pi$

Standard Model predictions can be obtained for the SM observables in presence of $O(\Lambda_{QCD}/m_b)$ correction (as for $S(K^0\pi^0)$ vs $C(K^0\pi^0)$)

There is homework for everybody

We need more precise measurements (Belle, LHCb, and maybe a superB)

Can the different models (QCD fact, pQCD, SCET, SU(3) based approaches?) predict the values obtained by these fits to data?