γ FROM LOOPS

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Introduction

γ from two-body $B_{(s)}$ decays

γ from three-body $B_{(s)}$ decays

Conclusions

INTRODUCTION

- The extraction of γ from penguin decays is sensitive to NP
- Some knowledge of hadronic parameters is necessary
- Several strategies based on hadronic models and/or flavour symmetries
- Quantifying hadronic uncertanties is the main issue

MAKING GOOD USE OF $B_s \to K^+K^-$

- $A(B_d \to \pi^+\pi^-) = e^{i\gamma}\,T - Pe^{i\delta} = C(e^{i\gamma} - de^{i\delta})$
- $A(B_d \to \pi^0\pi^0) = (e^{i\gamma}\,T_0 e^{i\delta 0} + Pe^{i\delta})/\sqrt{2}$
- $A(B^+ \to \pi^+\pi^0) = A(B_d \to \pi^+\pi^-)/\sqrt{2} + A(B_d \to \pi^0\pi^0)$
- Gronau-London: use the three BR's, S_{+-}, C_{+-} and C_{00} to determine T, T_0, δ_0, P, δ and γ (given 2β)
- Discrete ambiguities, singular solutions

- $A(B_s \to K^+K^-) = 1/\lambda\,(\lambda^2 e^{i\gamma} T' + P' e^{i\delta'}) =$

  $= \lambda\, C'(e^{i\gamma} + 1/\lambda^2\, d' e^{i\delta'})$
- $C' = C$, $d' = d$ and $\delta' = \delta$ in the U-spin limit
- U-spin breaking largely cancels in d'/d
- Fleischer: Use BR, S and C in $\pi^+\pi^-$ together with U-spin to extract T, P, δ and γ (given 2β and $2\beta_s$).

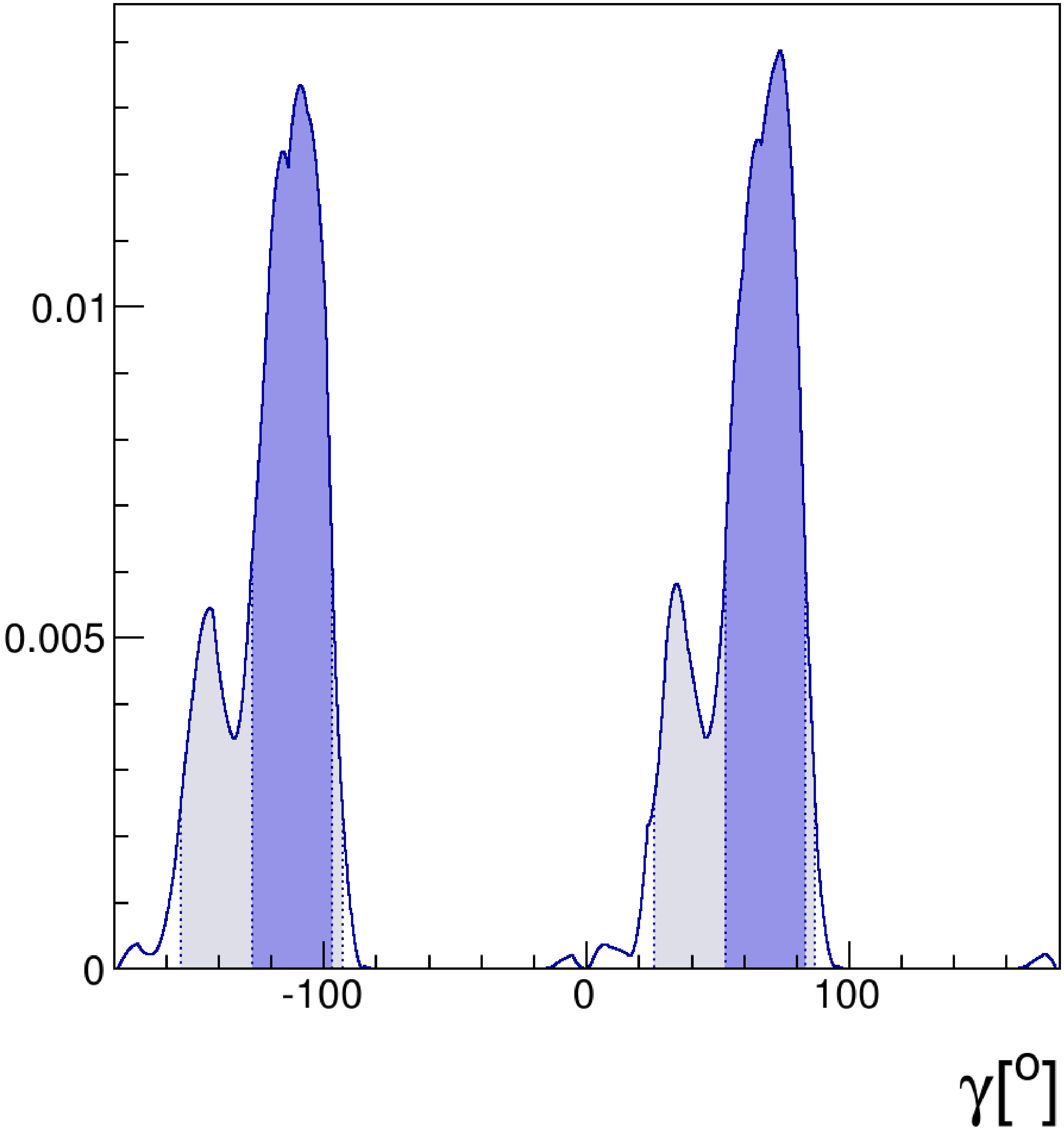
  Fleischer 99; Fleischer & Matias 02; London, Matias & Virto 05; Baek, London, Matias & Virto 06; Fleischer 07; Fleischer & Knegjens 10;...
- Pros: allows “LHCb only” determination of γ
- Cons: strongly depends on SU(3) breaking, can't be combined with GL

- Best strategy: combine $B_s \to K^+K^-$ with GL $B \to \pi\pi$ to obtain an improved determination of γ
- Present experimental input:

Channel	BR $\times 10^6$	$S(\%)$	$A(=-C)(\%)$	corr.	ref.
$B_d \to \pi^+\pi^-$	5.11 ± 0.22	-65 ± 7	38 ± 6	0.08	HFAG
$B_d \to \pi^+\pi^-$	–	$-56 \pm 17 \pm 3$	$11 \pm 21 \pm 3$	-0.34	LHCb
$B_d \to \pi^0\pi^0$	1.91 ± 0.23	–	43 ± 24	–	HFAG
$B^+ \to \pi^+\pi^0$	5.48 ± 0.35	–	–	–	HFAG
$B_s \to K^+K^-$	25.4 ± 3.7	$17 \pm 18 \pm 5$	$2 \pm 18 \pm 4$	-0.1	HFAG, LHCb

plus $\sin 2\beta = 0.679 \pm 0.024$, $\sin 2\beta_s = 0. \pm 0.101 \pm 0.027$

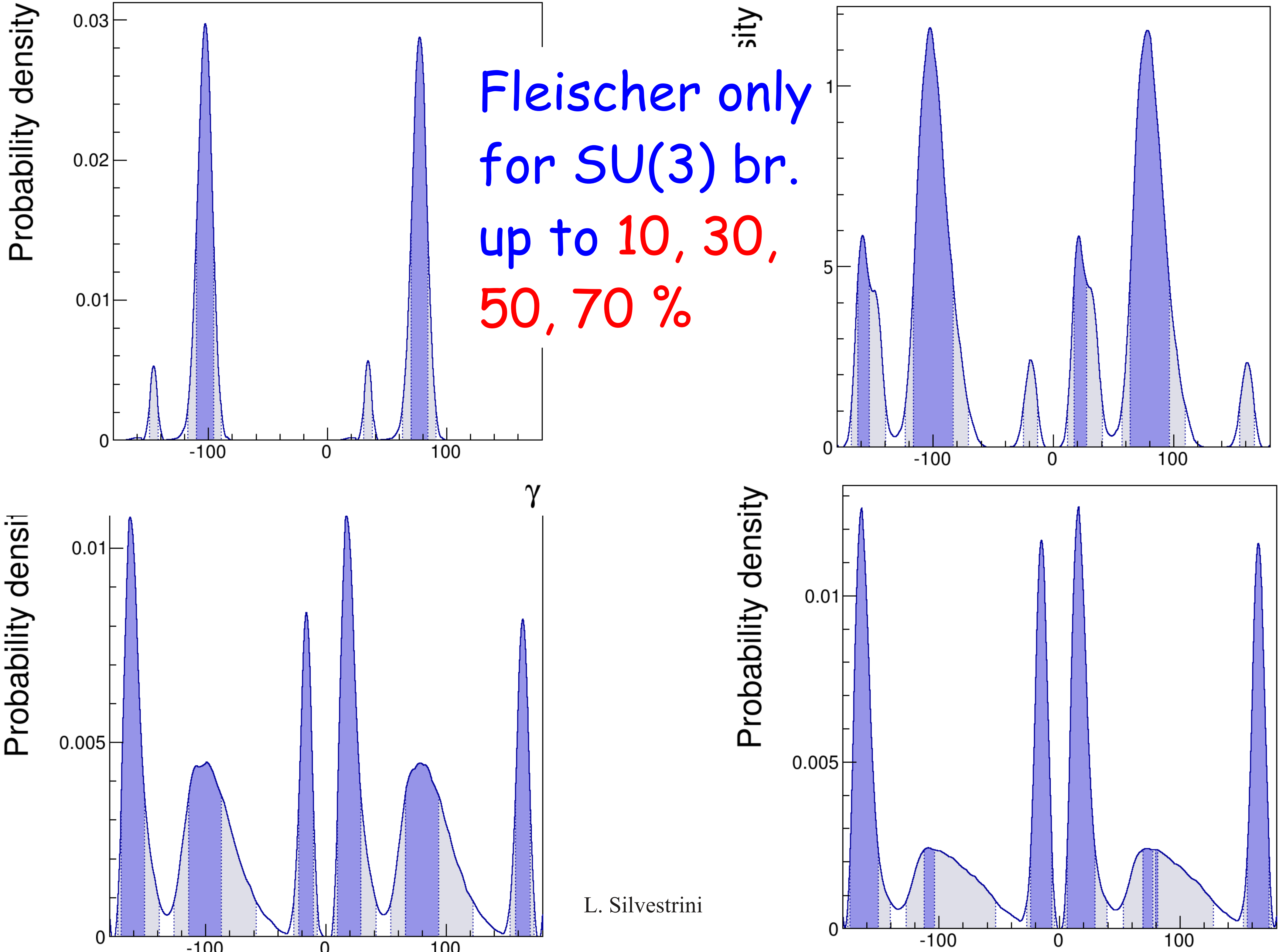
- VERY PRELIMINARY RESULTS, work in progress...



Gronau-London only:

$\gamma = (68 \pm 15)^\circ$

$[53, 83]^\circ$ @ 95%



Fleischer only for SU(3) br. up to 10, 30, 50, 70 %

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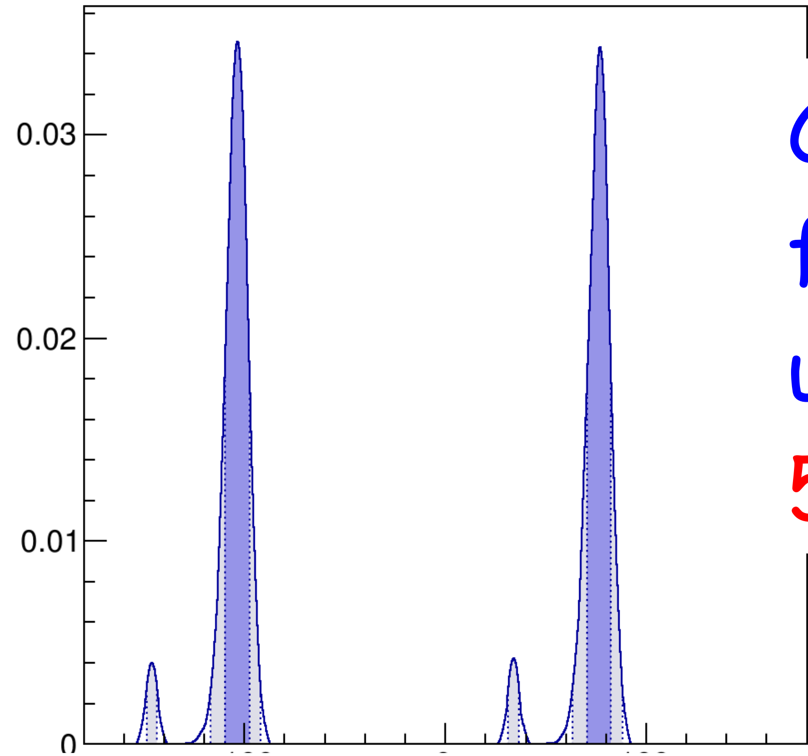
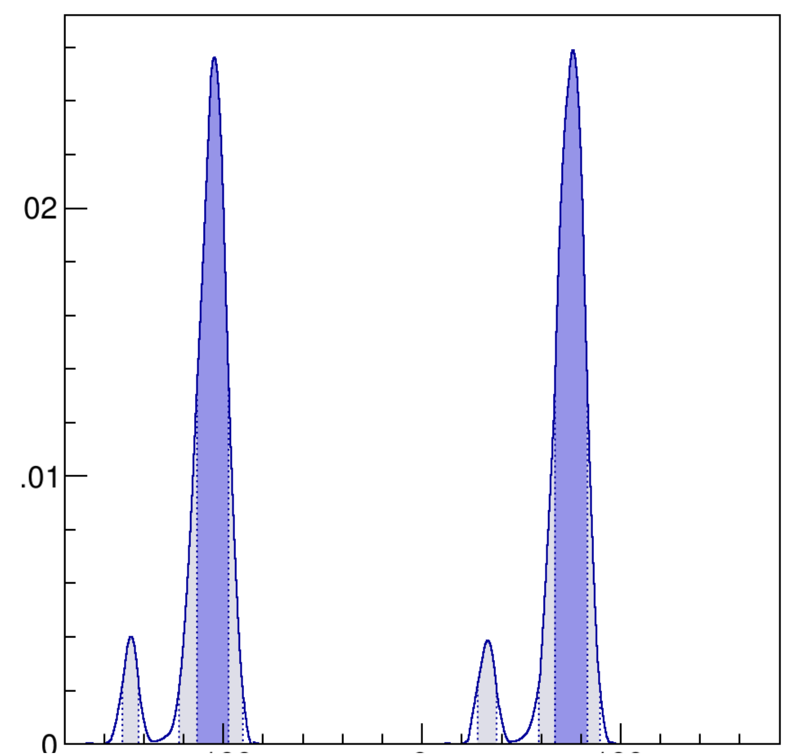
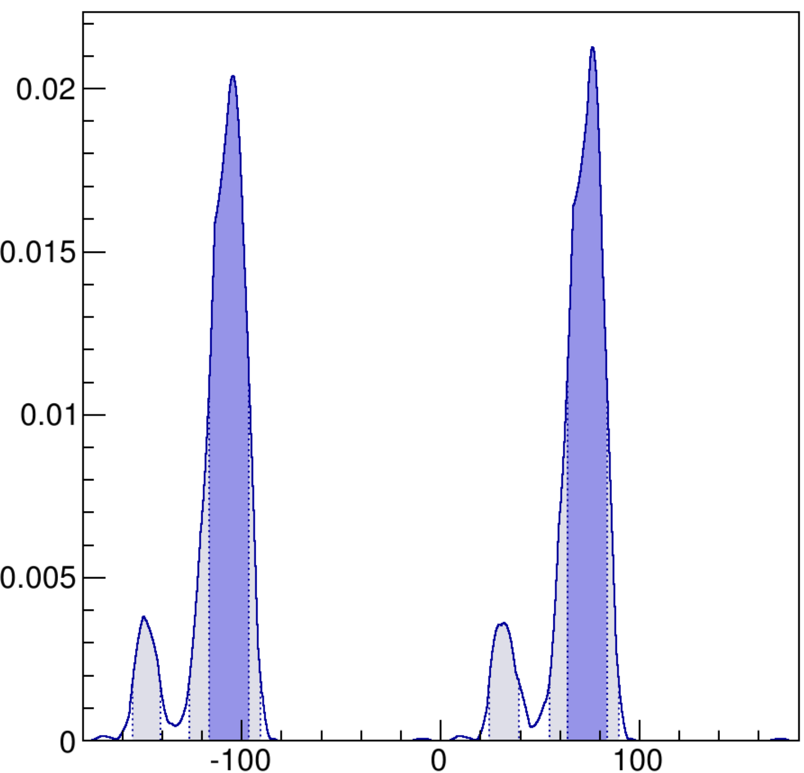
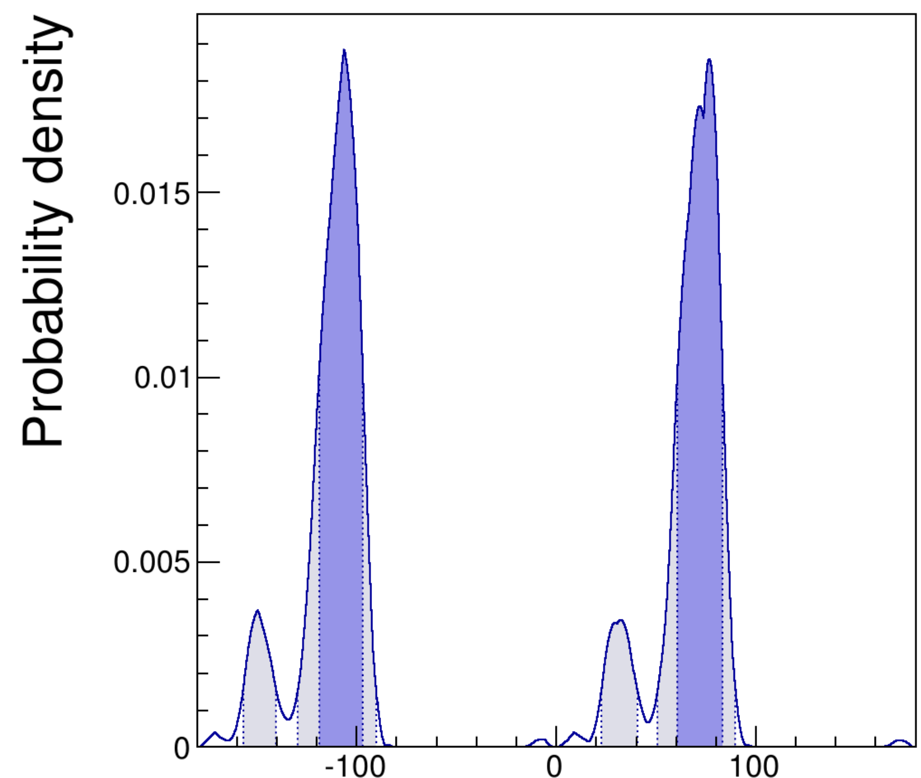
Combination for SU(3) br. up to 10, 30, 50, 70 %









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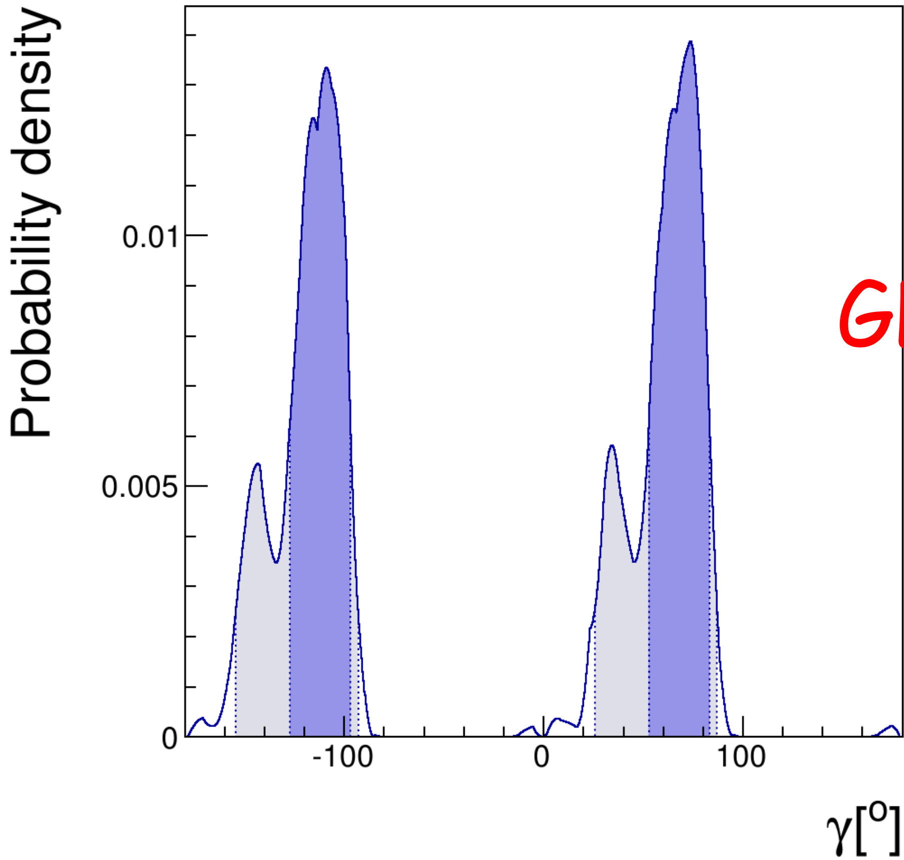
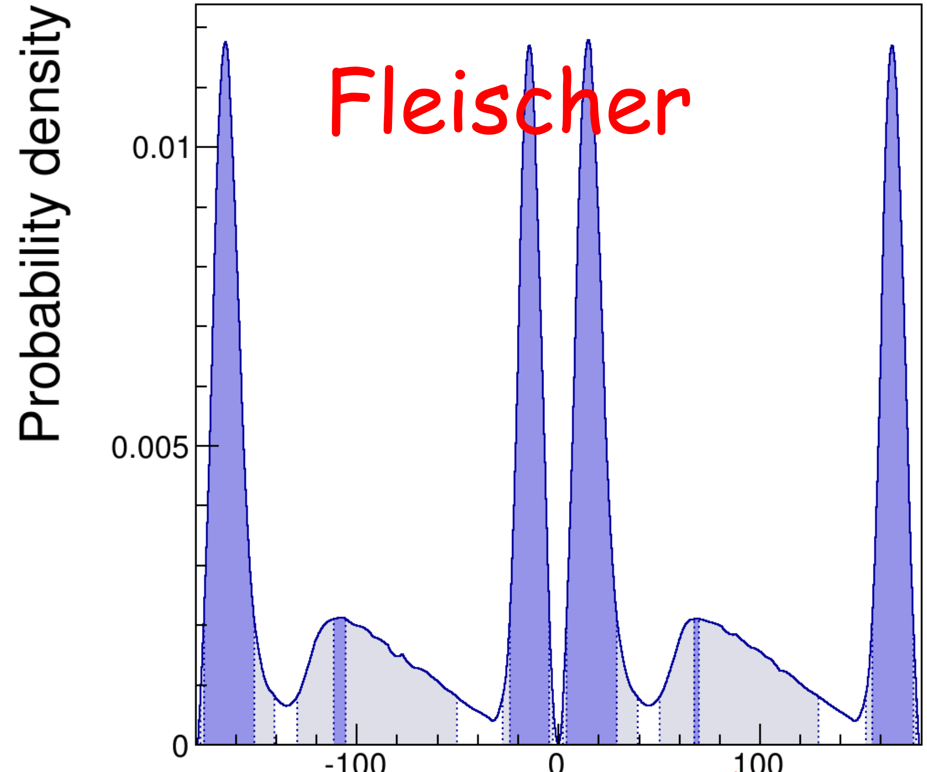
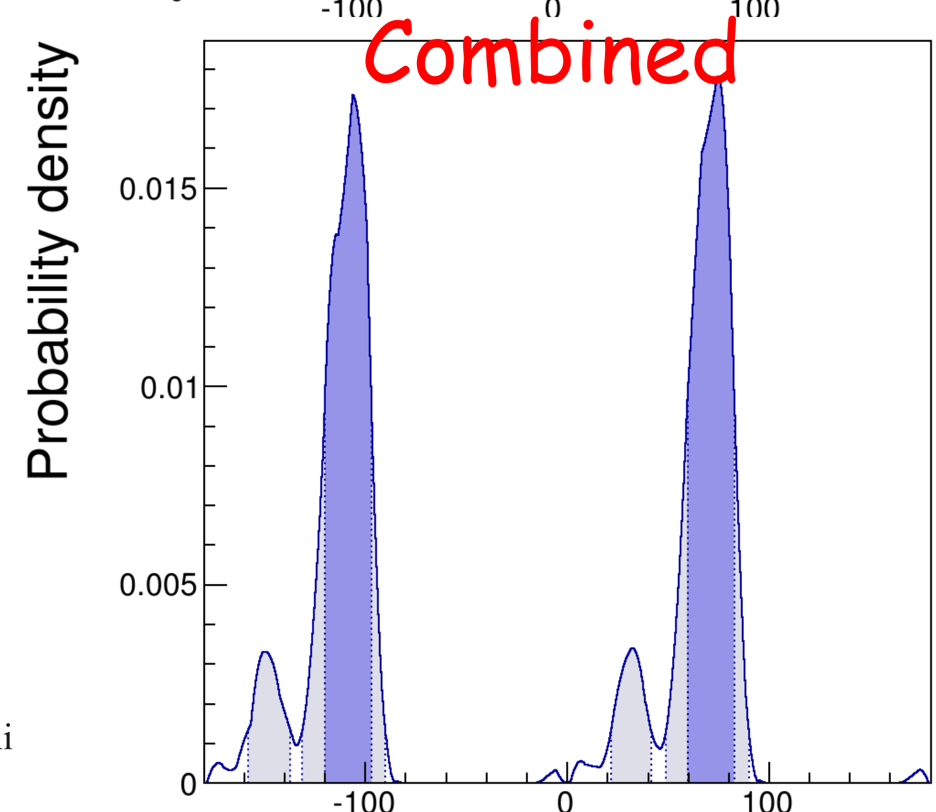
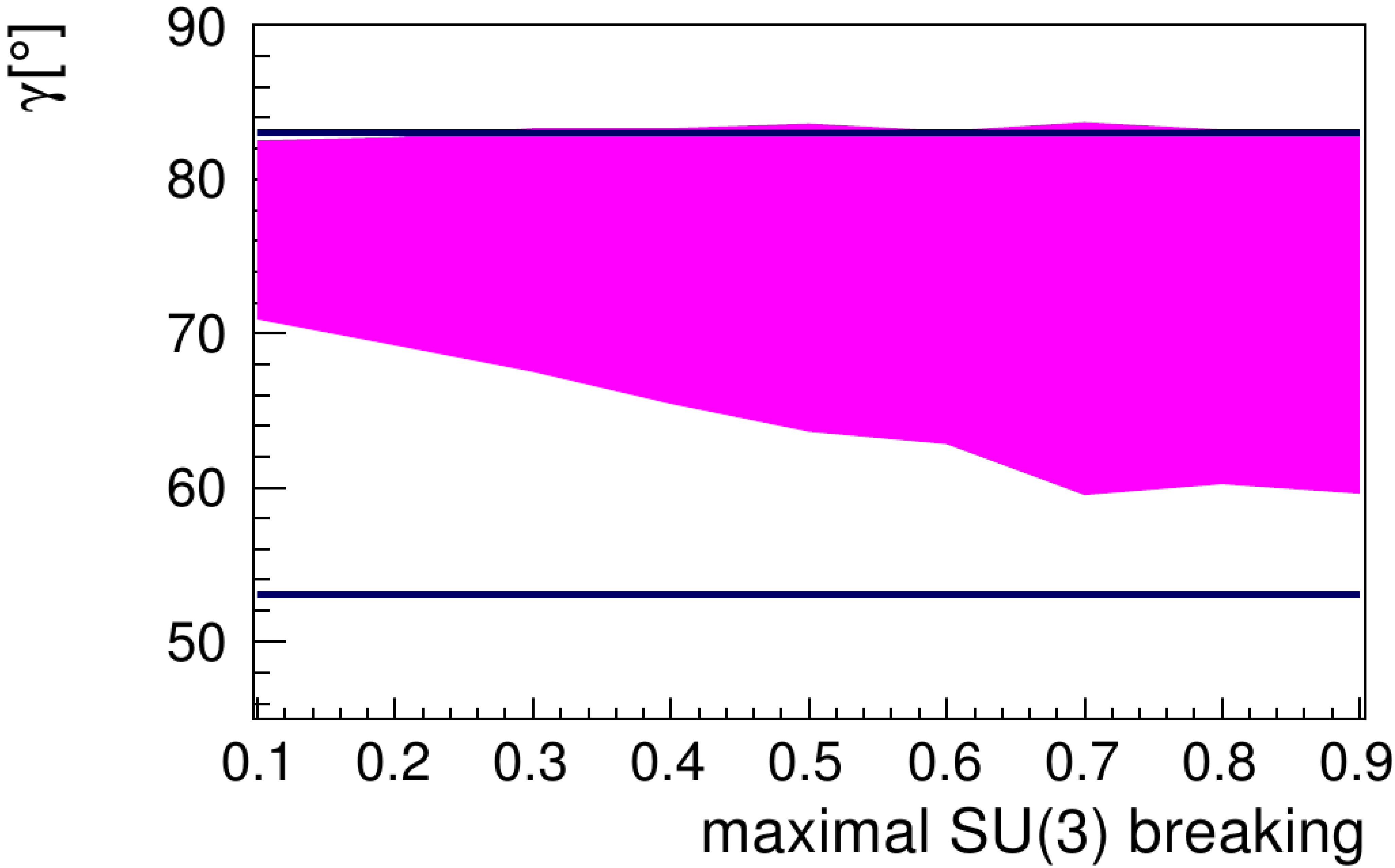






Even for 90% SU(3) breaking $B_s \to K^+K^-$ still plays a relevant role in cutting the small gamma region

68% prob. region for GL only and GL+KK



γ FROM $B_d \to K^*\pi$

- Idea: isolate tree decay amplitude using a Dalitz plot analysis and extract its phase

Ciuchini, Pierini & L.S. 06;
Gronau, Pirjol, Soni & Zupan 06, 07; ...

$$
\begin{aligned}
A(K^{*+}\pi^-) &= V_{tb}^* V_{ts} P_1 - V_{ub}^* V_{us}(E_1 - P_1^{\mathrm{GIM}}) \\
\sqrt{2}A(K^{*0}\pi^0) &= -V_{tb}^* V_{ts} P_1 - V_{ub}^* V_{us}(E_2 + P_1^{\mathrm{GIM}}) \\
\sqrt{2}A(K^{*+}\pi^0) &= V_{tb}^* V_{ts} P_1 \\
&\quad -V_{ub}^* V_{us}(E_1 + E_2 + A_1 - P_1^{\mathrm{GIM}}) \\
A(K^{*0}\pi^+) &= -V_{tb}^* V_{ts} P_1 + V_{ub}^* V_{us}(A_1 - P_1^{\mathrm{GIM}})
\end{aligned}
$$

- Neglecting EWP one has

$$
\begin{aligned}
A^0 &= A(K^{*+}\pi^-) + \sqrt{2}A(K^{*0}\pi^0) \\
&= -V_{ub}^* V_{us}(E_1 + E_2)\,, \\
\bar{A}^0 &= A(K^{*-}\pi^+) + \sqrt{2}A(\bar{K}^{*0}\pi^0) \\
&= -V_{ub} V_{us}^*(E_1 + E_2)\,,
\end{aligned}
\quad \longrightarrow \quad R^0 = \frac{\bar{A}^0}{A^0} = \frac{V_{ub}V_{us}^*}{V_{ub}^* V_{us}} = e^{-2i\gamma}
$$

$$
\begin{aligned}
A^+ &= A(K^{*0}\pi^+) + \sqrt{2}A(K^{*+}\pi^0) \\
&= -V_{ub}^* V_{us}(E_1 + E_2)\,, \\
A^- &= A(\bar{K}^{*0}\pi^-) + \sqrt{2}A(K^{*-}\pi^0) \\
&= -V_{ub} V_{us}^*(E_1 + E_2)\,,
\end{aligned}
\quad \longrightarrow \quad R^{\mp} = \frac{A^-}{A^+} = e^{-2i\gamma}
$$

Main issues:

- how to measure the relative phase of amplitudes entering different Dalitz plots or not directly interfering
- how to take into account effects of EWP
- original proposal requires measuring Dalitz plots with π^0s and time-dependent $K_S\pi^+\pi^- \Rightarrow$ hard for LHCb

- Bediaga et al. '07 suggest to use $K^{\pm}\pi^{+}\pi^{-}$ and time-integrated $K_S\pi^{+}\pi^{-}$, fixing the relative phases of Dalitz plots using $K\chi_c$ decays. Additional assumptions needed:
  - interference with $K\chi_c$ effective in determining the phase of $K^{*}\pi$ amplitudes
  - $K^{*0}\pi^{+}$ is dominated by P_1
- Must still correct for EWP effects

- If we could afford a π^0, the simplest strategy would be as follows:
  - assume $K^{*0}\pi^+$ is dominated by $P_1 \Rightarrow$ No direct CPV in $K^{*0}\pi^+$
  - fix arg $A(K^{*0}\pi^+)$ = arg $A(K^{*0}\pi^-) = 0$ and connect the $K_S\pi^+\pi^0$ and $K_S\pi^-\pi^0$ Dalitz plots
  - extract A^+, A^-, and γ
- The assumption of P_1 dominance can be relaxed by using $K\chi_c$ to fix the relative phase of $K_S\pi^+\pi^0$ and $K_S\pi^-\pi^0$ Dalitz plots

γ FROM $B_s \to K^*\pi$

- Quark level transition is $b \to d\,\bar{q}\,q$ $(q=u,d)$
  - tree contribution ($V_{ub}\,V_{ud}^*$) is not Cabibbo suppressed w.r.t. $V_{tb}V_{td}^*$
  - electroweak penguins are negligible
- $A(B_s \to K^{*-}\pi^+)$ and $A(B_s \to K^{*0}\pi^0)$ can be extracted from $B_s \to K^-\pi^+\pi^0$ Dalitz plot, and the conjugate amplitudes from $B_s \to K^+\pi^-\pi^0$

Ciuchini, Pierini & L.S. 06;
Gronau, Pirjol, Soni & Zupan 06, 07

- To obtain the relative phase of the $B_s \to K^- \pi^+ \pi^0$ and $\overline{B}_s \to K^+ \pi^- \pi^0$ Dalitz plots, use the $B_s \to K_S\, \pi^+ \pi^-$ Dalitz plot, exploiting interference of $K^{*+}\pi^-$ and $K^{*-}\pi^+$ with $\rho^0 K_S$ and other $\pi^+ \pi^-$ resonances.
- At hadron colliders, the sensitivity is given by the Re $\lambda\, \Delta\Gamma_s/\Gamma_s$ term in the time-integrated rate ($\lambda = q/p\; \overline{A}/A$).

CONCLUSIONS

- $B_s \to K^+K^-$ can be combined with standard GL analysis to improve considerably the determination of γ, even allowing for sizable SU(3) breaking effects
- The consistency of GL with $B_s \to K^+K^-$ is a test of NP in $b \to s$ penguins

CONCLUSIONS - II

- Tree-level amplitudes can be successfully isolated in $B_{(s)} \to K^*\pi$ decays using Dalitz analyses
- While optimal strategies require Dalitz plots with π^0s, first attempts could be made with $K^\pm\pi^+\pi^-$ and $K_S\pi^+\pi^-$ only