New physics searches via photon polarization measurements of b→sγ

Emi KOU (LAL/IN2P3-Orsay)

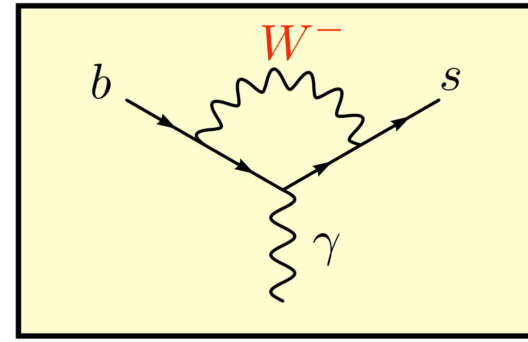
in collaboration with A.Tayduganov, A.LeYaouanc, D. Becirevic F.-S. Yu & J. Hebinger

Flavour of new physics in b-> s transitions

IHP (Paris)

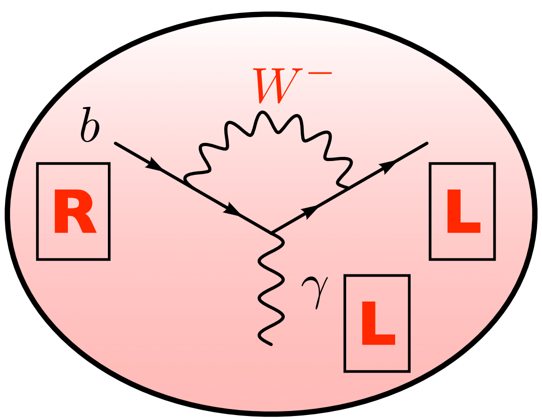
2-3rd June 2014

The b→sγ processes in SM

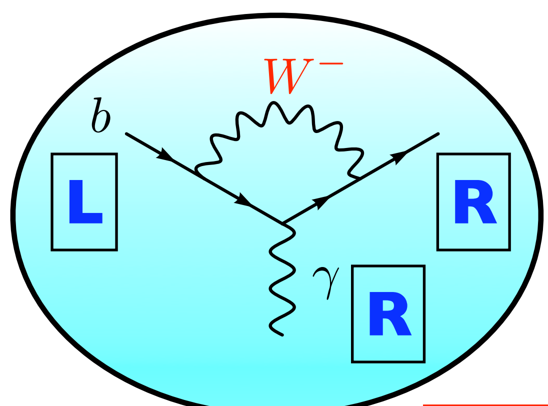


- The b →sγ process is a good probe of fundamental properties of SM as well as BSM (CKM, top mass, new particle mass etc..)
- Especially, the b→sγ process has a particular structure in SM.
- The requirement of the chirality flip leads to a left-photon dominance.

$$m_b \bar{s}_L \sigma_{\mu\nu} q^\nu b_R$$



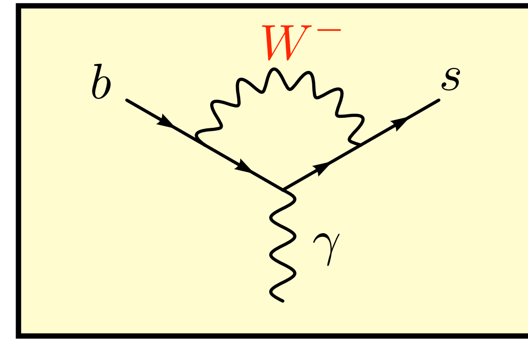
$$m_s \bar{s}_R \sigma_{\mu\nu} q^\nu b_L$$



In the SM, the opposite chirality is suppressed by ms/mb

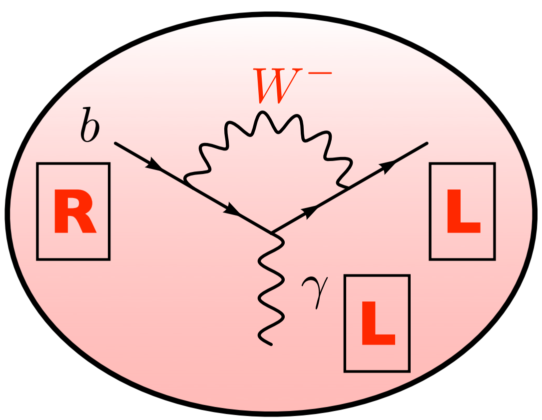
Unknown charm contribution under discussions!

The b→sγ processes in SM



- The b →sγ process is a good probe of fundamental properties of SM as well as BSM (CKM, top mass, new particle mass etc..)
- Especially, the b→sγ process has a particular structure in SM.
- The requirement of the chirality flip leads to a left-photon dominance.

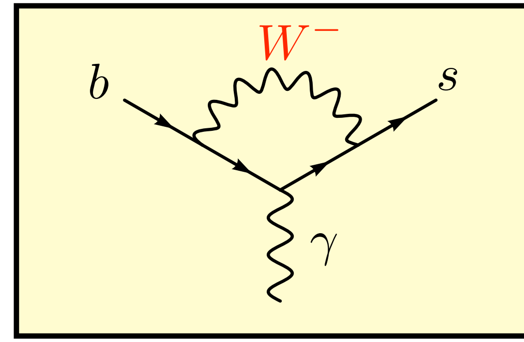
$$m_b \bar{s}_L \sigma_{\mu\nu} q^\nu b_R$$



W-boson coupling left-handedly, leads to the circular polarization of photon

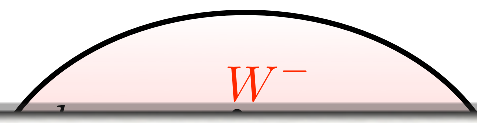
- b →s γ_L (left-handed polarization)
- $\bar{b}$ →$\bar{s}$ γ_R (right-handed polarization)

The b→sγ processes in SM



- The b →sγ process is a good probe of fundamental properties of SM as well as BSM (CKM, top mass, new particle mass etc..)
- Especially, the b→sγ process has a particular structure in SM.
- The requirement of the chirality flip leads to a left-photon dominance.

$$m_b \bar{s}_L \sigma_{\mu\nu} q^\nu b_R$$

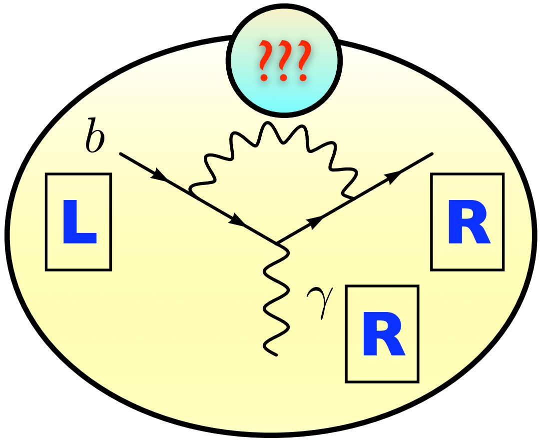


W-boson coupling left-handedly, leads to the circular polarization of photon

ation)
zation)

However, this left-handedness of the polarization of b →s γ has never been confirmed at a high precision yet!!

Right-handed: which NP model?



- **What types of new physics models?**
  For example, models with right-handed neutrino, or custodial symmetry in general induces the right handed current.

Left-Right symmetric model (W_R)	SUSY GUT model δ_{RR} mass insertion
Blanke et al. JHEP1203	*Girrbach et al. JHEP1106*

- **Which flavour structure?**
  The models that contain new particles which change the chirality inside of the b→sγ loop can induce a large chiral enhancement!

Left-Right symmetric model: mt/mb	SUSY with δ_{RL} mass insertions: m_{SUSY}/mb
Cho, Misiak, PRD49, '94 *Babu et al PLB333 '94*	*Gabbiani, et al. NPB477 '96* *Ball, EK, Khalil, PRD69 '04*

NP signal beyond the constraints from Bs oscillation parameters possible.

Example: Left-Right Symmetric Model

Extended gauge group

$$SU(2)_L \times SU(2)_R \times U(1)_{\tilde{Y}} \to SU(2)_L \times U(1)_Y \to U(1)_{\mathrm{EM}}.$$

[Pati,Salam,1974;Mohapatra,Pati,1975;Mohapatra,Sejanovic,1975]

Two step Symmetry breakings

$$\langle\Phi\rangle = \begin{pmatrix} \kappa & 0 \\ 0 & \kappa' e^{i\omega} \end{pmatrix}, \quad \langle\Delta_L\rangle = \begin{pmatrix} 0 & 0 \\ v_L e^{i\theta_L} & 0 \end{pmatrix}, \quad \langle\Delta_R\rangle = \begin{pmatrix} 0 & 0 \\ v_R & 0 \end{pmatrix}$$

$$\kappa, \kappa', v_L \ll v_R$$

Right handed mass very large

W boson with left- and right-handed couplings (W_L & W_R)

$$\begin{pmatrix} W_L^- \\ W_R^- \end{pmatrix} = \begin{pmatrix} \cos\zeta & -\sin\zeta e^{iw} \\ \sin\zeta e^{-iw} & \cos\zeta \end{pmatrix} \begin{pmatrix} W_1^- \\ W_2^- \end{pmatrix}$$

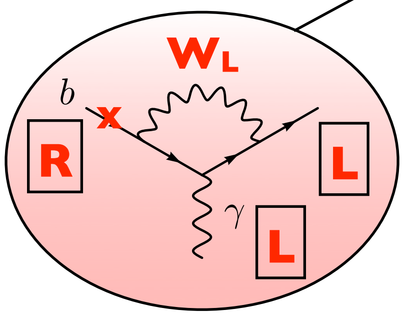
$$\sin\zeta \approx \frac{g_L}{g_R}\frac{|\kappa||\kappa'|}{v_R^2} = \frac{g_L}{g_R}\frac{1}{2}\epsilon^2 \sin 2\beta \approx \frac{M_{W_1}^2}{M_{W_2}^2}\frac{g_R}{g_L}\sin 2\beta.$$

Mass eigenstates W_1 & W_2 are a mixture of left and right W's

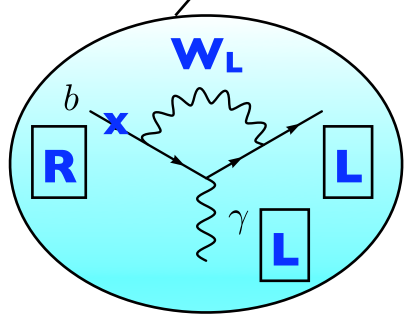
Example: Left-Right Symmetric Model

SM-like left handed-photon contribution

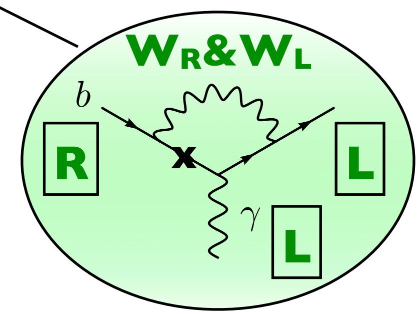
$$C_{7\gamma}(\mu_R) = \frac{1}{2}\Bigg[\cos^2\zeta A_{\mathrm{SM}}(x_t) + \sin^2\zeta \frac{M_1^2}{M_2^2} A_{\mathrm{SM}}(\tilde{x}_t) + \frac{m_t}{m_b}\frac{g_R}{g_L}\frac{V_{tb}^R}{V_{tb}^L}\sin\zeta\cos\zeta e^{iw}\left(A_{\mathrm{LR}}(x_t) - \frac{M_1^2}{M_2^2}A_{\mathrm{LR}}(\tilde{x}_t)\right) + \ldots$$



SM-like W_L contributions proportional to mb



W_L contribution from W_2; Proportional to mb but suppressed by $1/M_2^2$



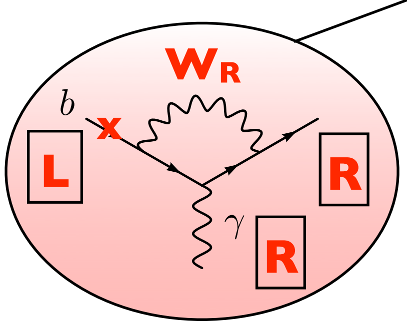
W_L & W_R mixing contribution; proportional to mt !

Chiral enhancement term

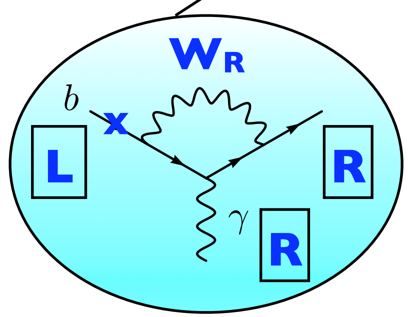
Example: Left-Right Symmetric Model

Right handed-photon contribution

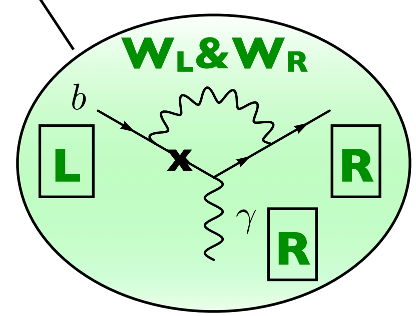
$$C'_{7\gamma}(\mu_R) = \frac{1}{2}\Bigg[\frac{g_R^2}{g_L^2}\frac{V_{ts}^{R*}V_{tb}^{R}}{V_{ts}^{L*}V_{tb}^{L}}\left(\sin^2\zeta A_{\rm SM}(x_t)+\cos^2\zeta\frac{M_1^2}{M_2^2}A_{\rm SM}(\tilde{x}_t)\right)$$
$$+\frac{m_t}{m_b}\frac{g_R}{g_L}\frac{V_{ts}^{R*}}{V_{ts}^{L*}}\sin\zeta\cos\zeta e^{-iw}\left(A_{\rm LR}(x_t)-\frac{M_1^2}{M_2^2}A_{\rm LR}(\tilde{x}_t)\right) + \ldots$$



W_R contribution from W_1;
Proportional to mb but
suppressed by $1/M_2^2$



W_R contribution from W_1;
Proportional to mb



W_L & W_R mixing
contribution;
proportional to mt !

Chiral enhancement term

By the way...

Is a right-handed contribution still allowed in b→sγ from experiment?

We can write the amplitude including RH contribution as:

$$\mathcal{M}(b \to s\gamma) \simeq -\frac{4G_F}{\sqrt{2}} V_{ts}^* V_{tb} \left[\underbrace{(C_{7\gamma}^{\rm SM} + C_{7\gamma}^{\rm NP})\langle \mathcal{O}_{7\gamma}\rangle}_{\propto \mathcal{M}_L} + \underbrace{C_{7\gamma}'^{\rm NP}\langle \mathcal{O}_{7\gamma}'\rangle}_{\propto \mathcal{M}_R} \right]$$

We have a constraint from inclusive branching ratio measurement

$$Br(B \to X_S\gamma) \propto |C_{7\gamma}^{\rm SM} + C_{7\gamma}^{\rm NP}|^2 + |C_{7\gamma}'^{\rm NP}|^2$$

While the polarization measurement carries information on

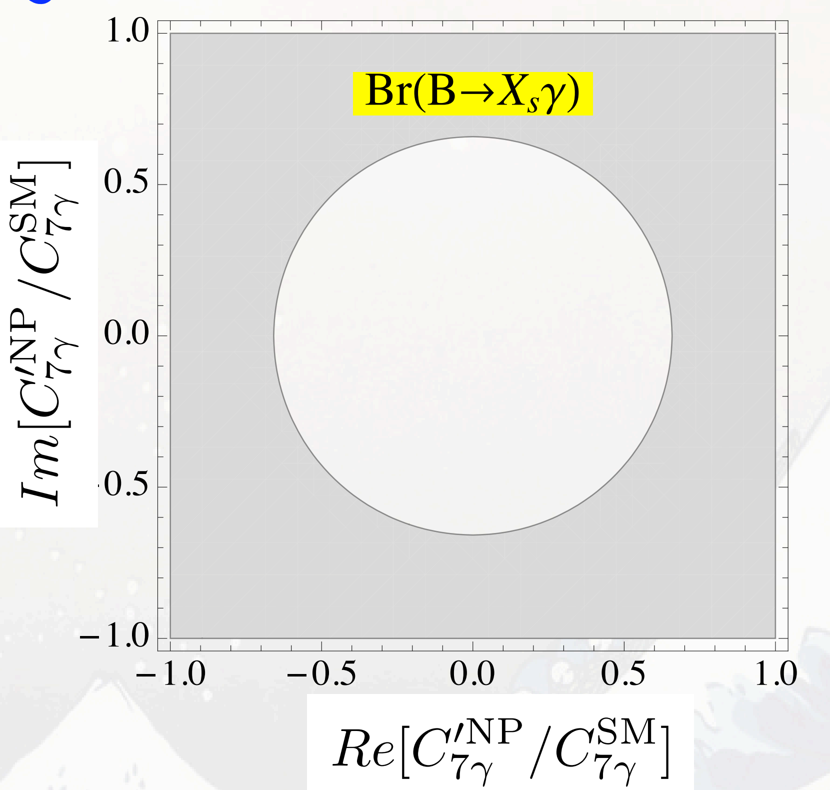
$$\frac{\mathcal{M}_R}{\mathcal{M}_L} \simeq \frac{C_{7\gamma}'^{\rm NP}}{C_{7\gamma}^{\rm SM} + C_{7\gamma}^{\rm NP}}$$

HFAG

$(3.55 \pm 0.24 \pm 0.09) \times 10^{-4}$

Here we assume $C'^{\rm NP}_{7\gamma} \neq 0$, $C^{\rm NP}_{7\gamma} = 0$

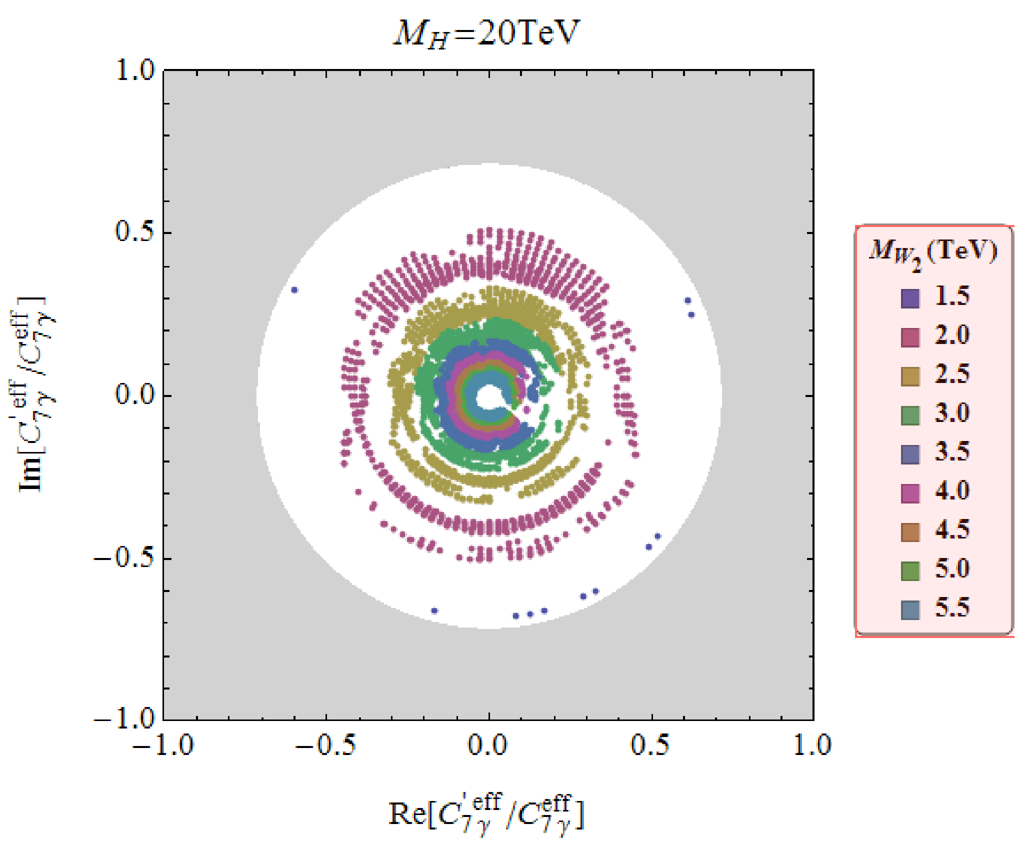
- SUSY with δ_{RL} mass insertions
- SUSY-GUT models
- etc...



Example: Left-Right Symmetric Model

E.K. C.D. Lu and F.S.Yu, JHEP ('13)

$$\frac{C'_{7\gamma}(\mu_b)}{C_{7\gamma}(\mu_b)} \sim -1180 \frac{g_R^2}{g_L^2} \frac{M_{W_1}^2}{M_{W_2}^2} \sin 2\beta \; V_{ts}^{R*} \; e^{-i\omega}$$



Model parameters; g_R/g_L=1, tan beta=10

How do we measure the polarization?!

proposed methods

- Method I: Time dependent CP asymmetry in $B_d \to K_S \pi^0 \gamma$ $B_s \to K^+ K^- \gamma$ (called $S_{K_S \pi^0 \gamma}$, $S_{K^+ K^- \gamma}$)
- Method II: Transverse asymmetry in $B_d \to K^* l^+ l^-$ (called $A_T^{(2)}$, $A_T^{(im)}$)
- Method III: $B \to K_1 (\to K \pi \pi) \gamma$ (called λ_γ)
- Method IV: $\Lambda_b \to \Lambda^{(*)} \gamma$, $\Xi_b \to \Xi^* \gamma$ ...

Atwood et.al. PRL79

Kruger, Matias PRD71
Becirevic, Schneider, NPB854

Gronau et al PRL88
E.K. Le Yaouanc, Tayduganov PRD83

Gremm et al.'95, Mannel et al '97, Legger et al '07, Oliver et al '10

How to measure the polarization?

Becirevic, EK, Le Yaouanc, Tayduganov in preparation

proposed methods

▸ Method I: Time dependent CP asymmetry in $B_d \to K_S \pi^0 \gamma$ $B_s \to K^+ K^- \gamma$ (called $S_{K_S\pi 0\gamma}$, $S_{K+K-\gamma}$)

$$S_{K_S\pi^0\gamma} = \frac{2|C_{7\gamma}^{\rm SM} C_{7\gamma}^{\prime \rm NP}|}{|C_{7\gamma}^{\rm SM}|^2 + |C_{7\gamma}^{\prime \rm NP}|^2} \sin(2\phi_1 - \phi_R) \qquad \phi_R = \arg\left[\frac{C_{7\gamma}^{\prime \rm NP}}{C_{7\gamma}^{\rm SM}}\right]$$

▸ Method II: Transverse asymmetry in $B_d \to K^* l^+ l^-$ (called $A_T^{(2)}$, $A_T^{(im)}$)

$$\mathcal{A}_T^{(2)}(q^2=0) = \frac{2Re[C_{7\gamma}^{\rm SM} C_{7\gamma}^{\prime \rm NP *}]}{|C_{7\gamma}^{\rm SM}|^2 + |C_{7\gamma}^{\prime \rm NP}|^2} \qquad \mathcal{A}_T^{(im)}(q^2=0) = \frac{2Im[C_{7\gamma}^{\rm SM} C_{7\gamma}^{\prime \rm NP *}]}{|C_{7\gamma}^{\rm SM}|^2 + |C_{7\gamma}^{\prime \rm NP}|^2}$$

Assumption for γ^*/Z penguin (C_9, C_{10} contributions) necessary!

▸ Method III: $B \to K_1 (\to K\pi\pi)\gamma$ (called λ_γ)

$$\lambda = \frac{|C_{7\gamma}^{\prime \rm NP}|^2 - |C_{7\gamma}^{\rm SM}|^2}{|C_{7\gamma}^{\prime \rm NP}|^2 + |C_{7\gamma}^{\rm SM}|^2}$$

▸ Method IV: $\Lambda_b \to \Lambda^{(*)}\gamma$, $\Xi_b \to \Xi^* \gamma$ ...

Comparison of the three methods

Becirevic, EK, Le Yaouanc, Tayduganov in preparation

proposed methods

- **Method I**: Time dependent CP asymmetry in $B_d \to K_S \pi^0 \gamma$ $B_s \to K^+ K^- \gamma$ (called $S_{K_S\pi^0\gamma}$, $S_{K^+K^-\gamma}$)

$$S_{K_S\pi^0\gamma} = \frac{2|C_{7\gamma}^{SM} C_{7\gamma}^{\prime NP}|}{|C_{7\gamma}^{SM}|^2 + |C_{7\gamma}^{\prime NP}|^2}$$

LHCb/Belle II

$\sigma_{S_{K_S\pi\gamma}}(0.02)$

$$\phi_R = \arg\left[\frac{C_{7\gamma}^{\prime NP}}{C_{7\gamma}^{SM}}\right]$$

- **Method II**: Transverse asymmetry in $B_d \to K^* l^+ l^-$ (called $A_T^{(2)}$, $A_T^{(im)}$)

$$\mathcal{A}_T^{(2)}(q^2=0) = \frac{2Re[C_{7\gamma}^{SM} C_{7\gamma}^{\prime NP}}{|C_{7\gamma}^{SM}|^2 + |C_{7\gamma}^{\prime NP}}$$

LHCb

$\sigma_{A_T^{2(im)}}(0.2)$

$$\ldots{}^2 = 0) = \frac{2Im[C_{7\gamma}^{SM} C_{7\gamma}^{\prime NP*}]}{|C_{7\gamma}^{SM}|^2 + |C_{7\gamma}^{\prime NP}|^2}$$

- **Method III**: $B \to K_1 (\to K\pi\pi)\gamma$ (called λ_γ)

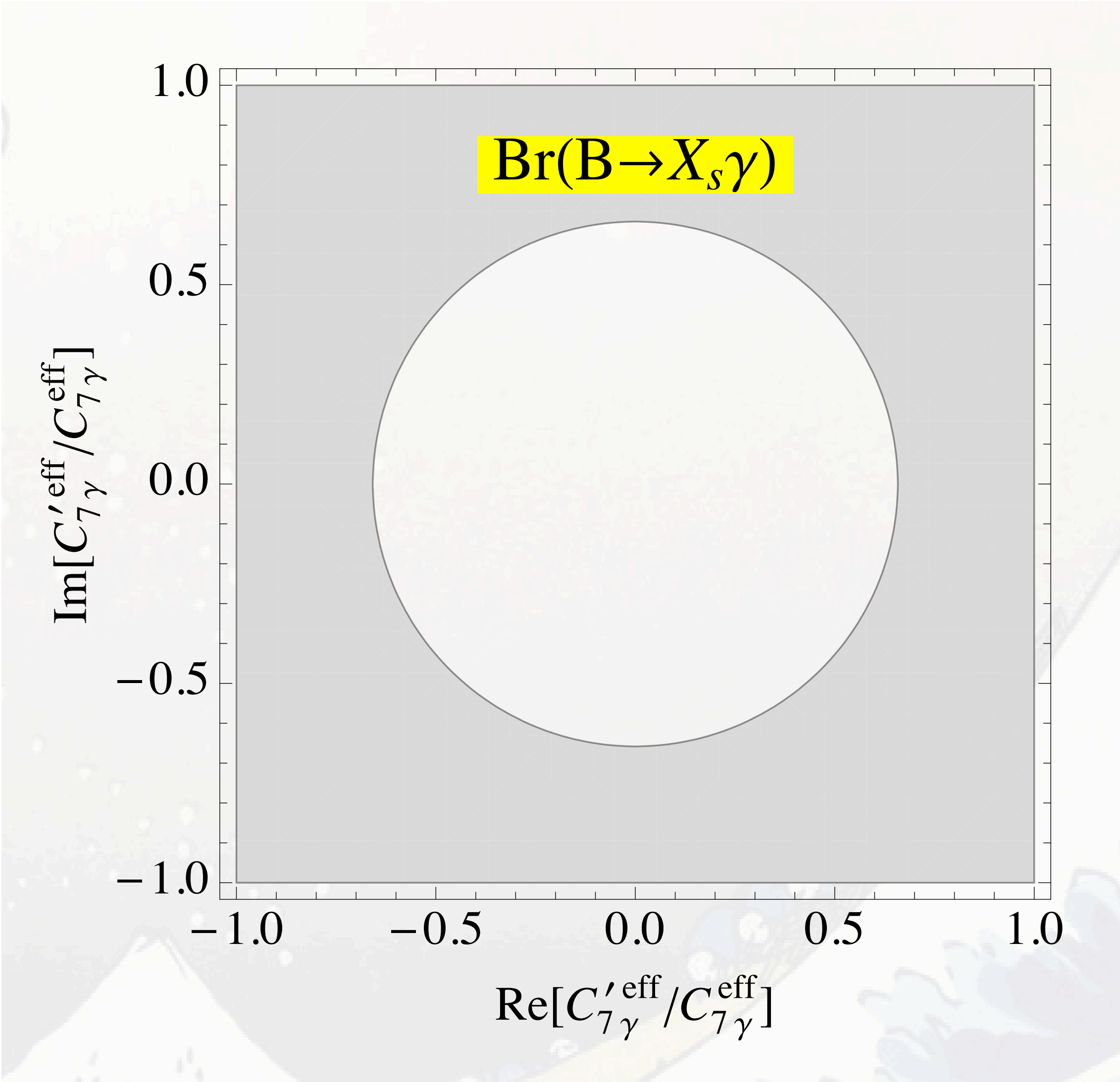
λ … ^{2} … ^{2}

LHCb/Belle II

$\sigma_\lambda(0.1\text{–}0.2)$

Comparison of the three methods

Becirevic, EK, Le Yaouanc, Tayduganov in preparation

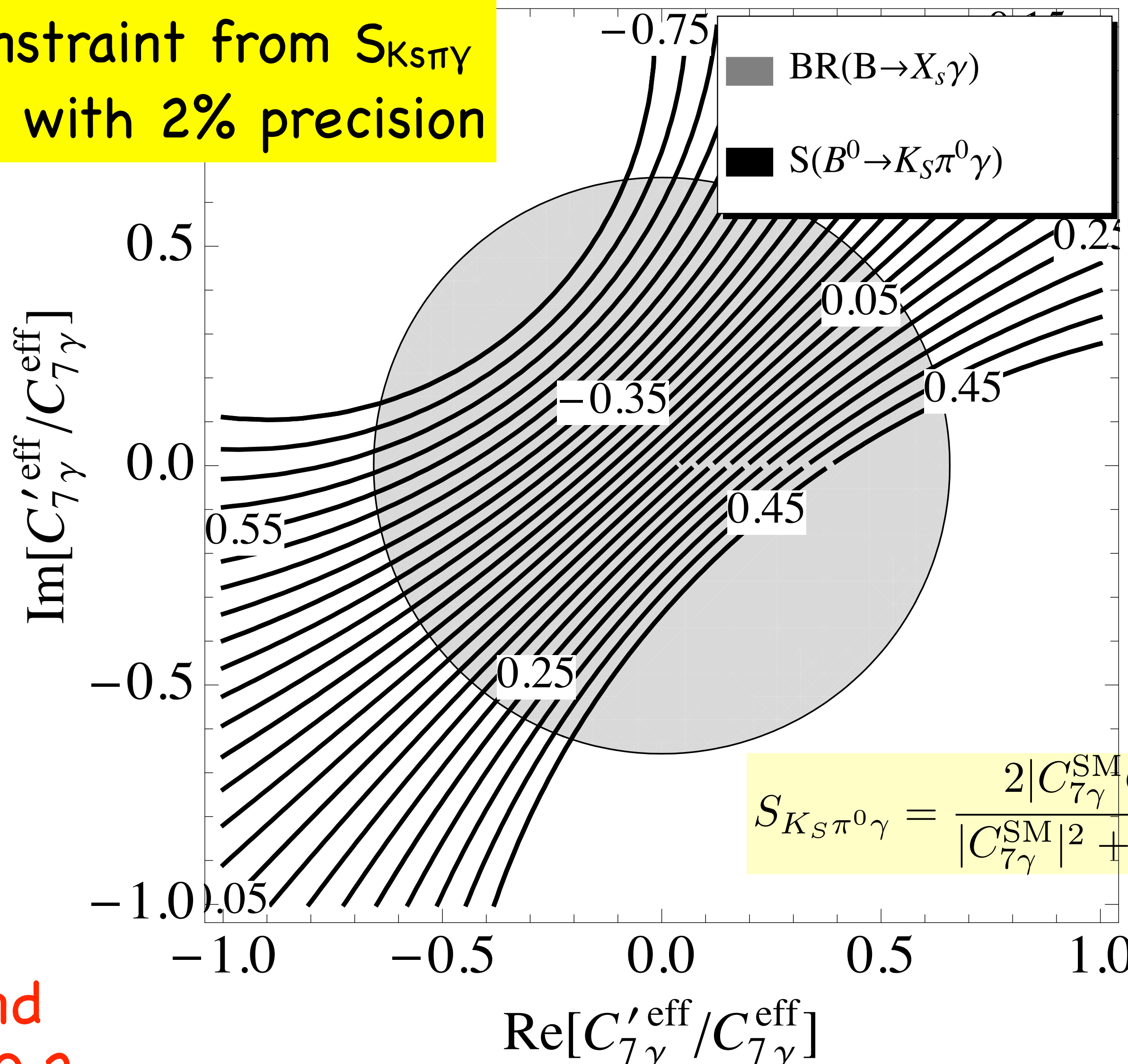


Comparison of the three methods

Becirevic, EK, Le Yaouanc, Tayduganov JHEP ('12)

Method I

Expected constraint from $S_{K_S\pi\gamma}$ measurement with 2% precision



$$S_{K_S\pi^0\gamma} = \frac{2|C_{7\gamma}^{\mathrm{SM}} C_{7\gamma}'^{\mathrm{NP}}|}{|C_{7\gamma}^{\mathrm{SM}}|^2 + |C_{7\gamma}'^{\mathrm{NP}}|^2} \sin(2\phi_1 - \phi_R)$$

Current bound

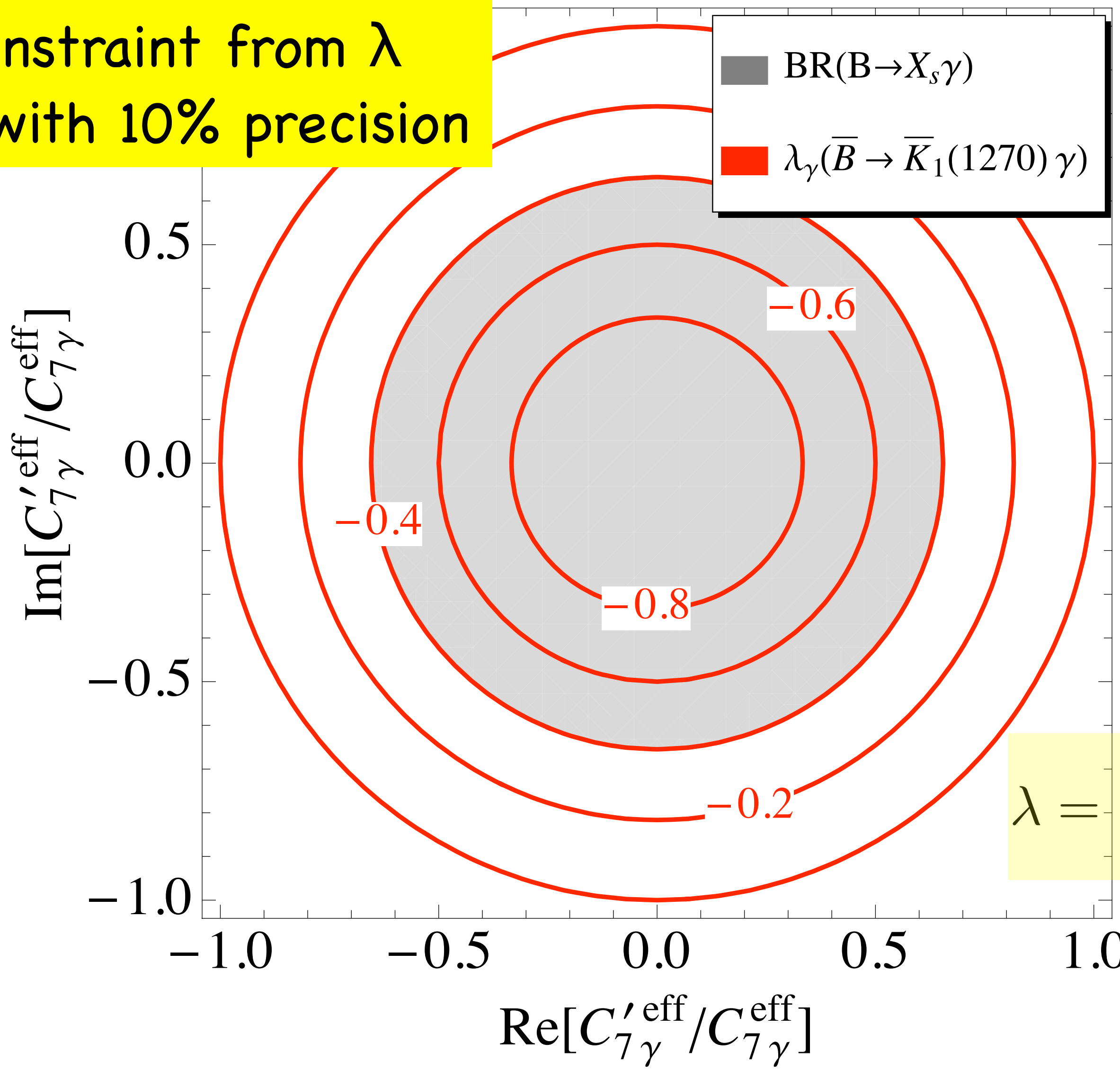
$S_{K_S\pi^0\gamma} = -0.15 \pm 0.2$

Comparison of the three methods

Becirevic, EK, Le Yaouanc, Tayduganov JHEP ('12)

Method III

Expected constraint from λ measurement with 10% precision

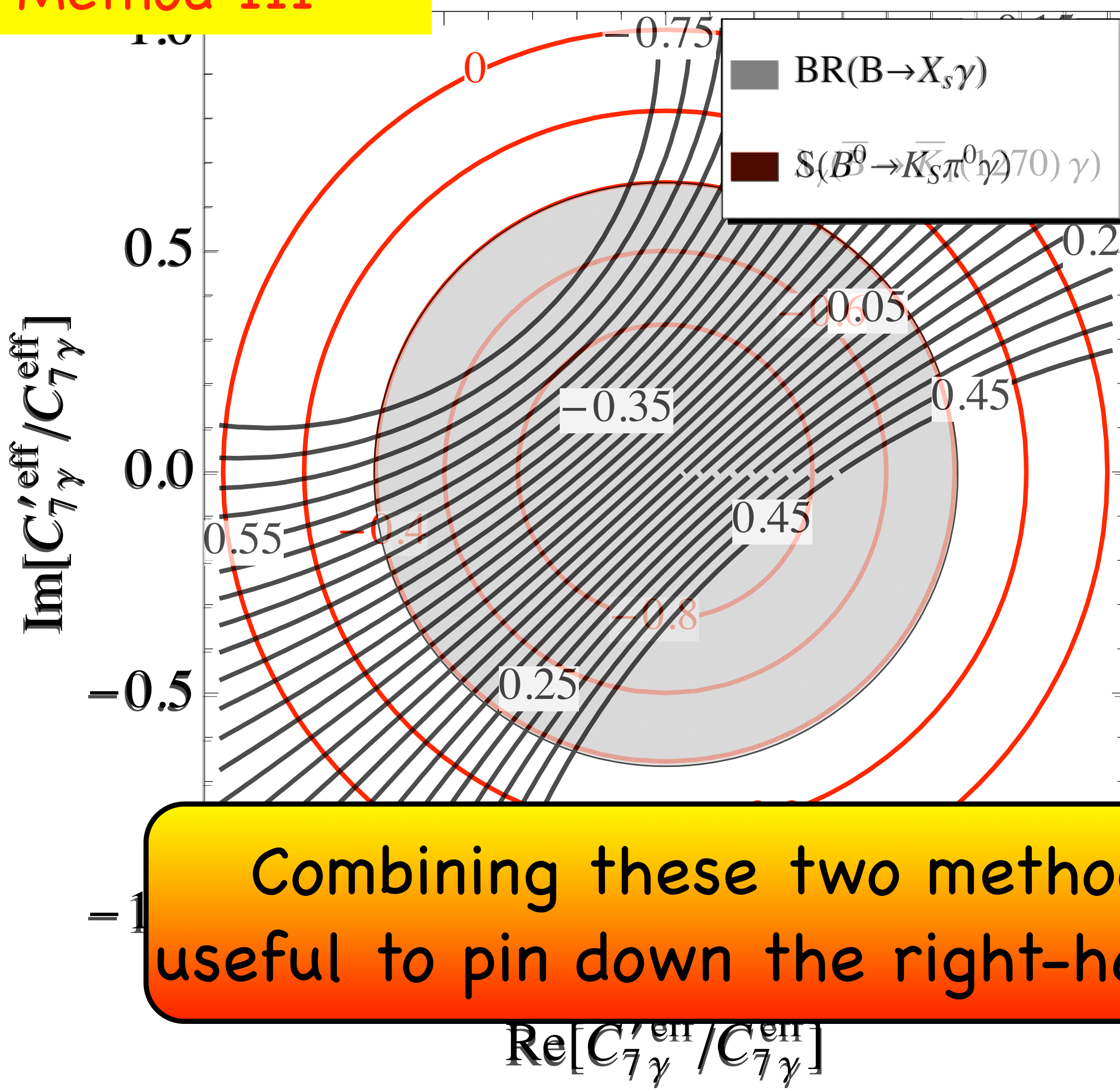


$$\lambda = \frac{|C'^{\mathrm{NP}}_{7\gamma}|^2 - |C^{\mathrm{SM}}_{7\gamma}|^2}{|C'^{\mathrm{NP}}_{7\gamma}|^2 + |C^{\mathrm{SM}}_{7\gamma}|^2}$$

Comparison of the three methods

Becirevic, EK, Le Yaouanc, Tayduganov JHEP ('12)

Method I & Method III



Combining these two methods are very useful to pin down the right-handed current!

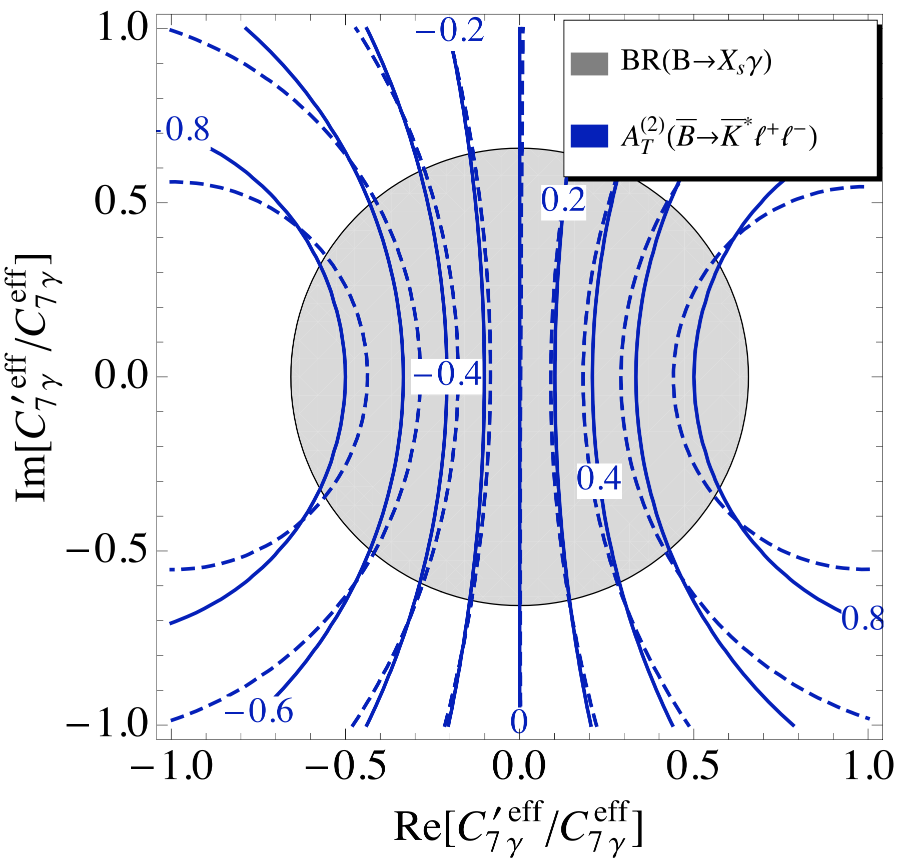
Comparison of the three methods

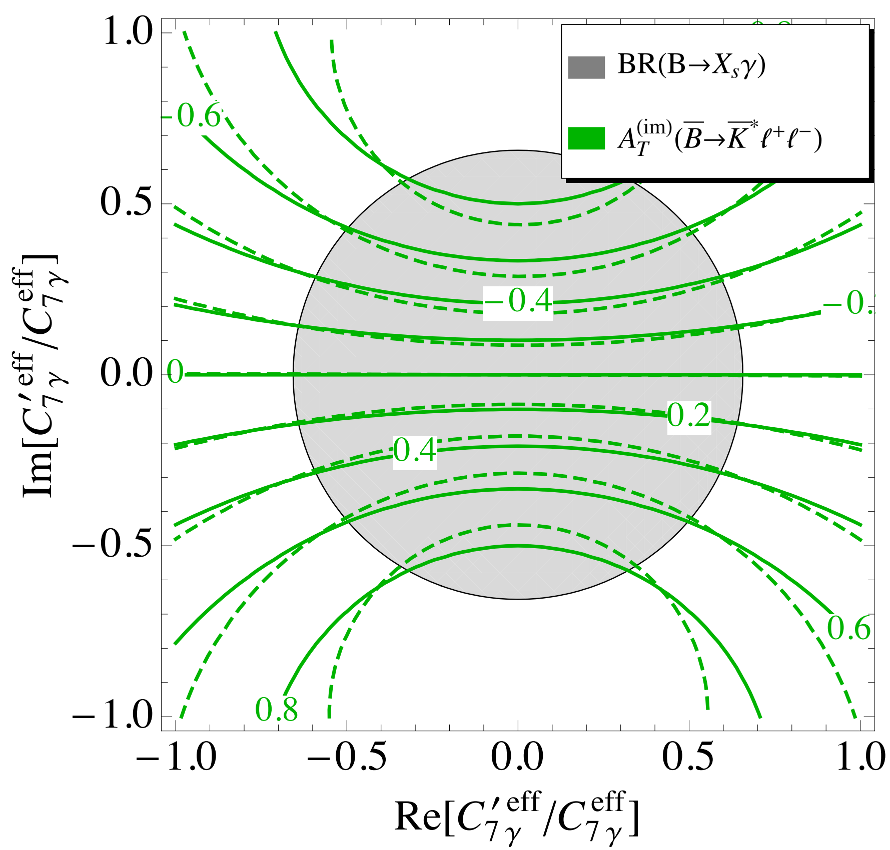
Becirevic, EK, Le Yaouanc, Tayduganov JHEP ('12)

Method II

Expected constraint from

$A_T^{(2)}$, $A_T^{(im)}$ measurement with 10% precision





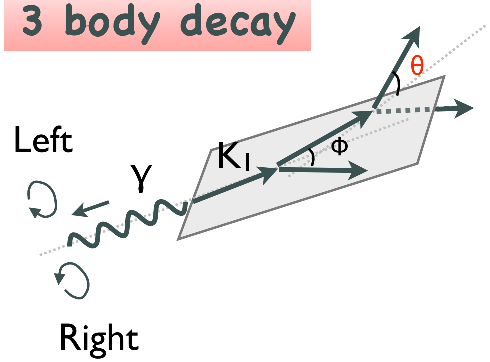
Assumption for γ*/Z penguin (C_9,C_{10} contributions) necessary!

Discussions

Interpreting Up-Down Asymmetry

Gronau, Grossman, Pirjol, Ryd PRL88('01)

3 body decay



$$\mathcal{A} = \frac{\int_0^1 \cos\theta \frac{d\Gamma}{d\cos\theta} - \int_{-1}^0 \cos\theta \frac{d\Gamma}{d\cos\theta}}{\int_{-1}^1 \cos\theta \frac{d\Gamma}{d\cos\theta}}$$

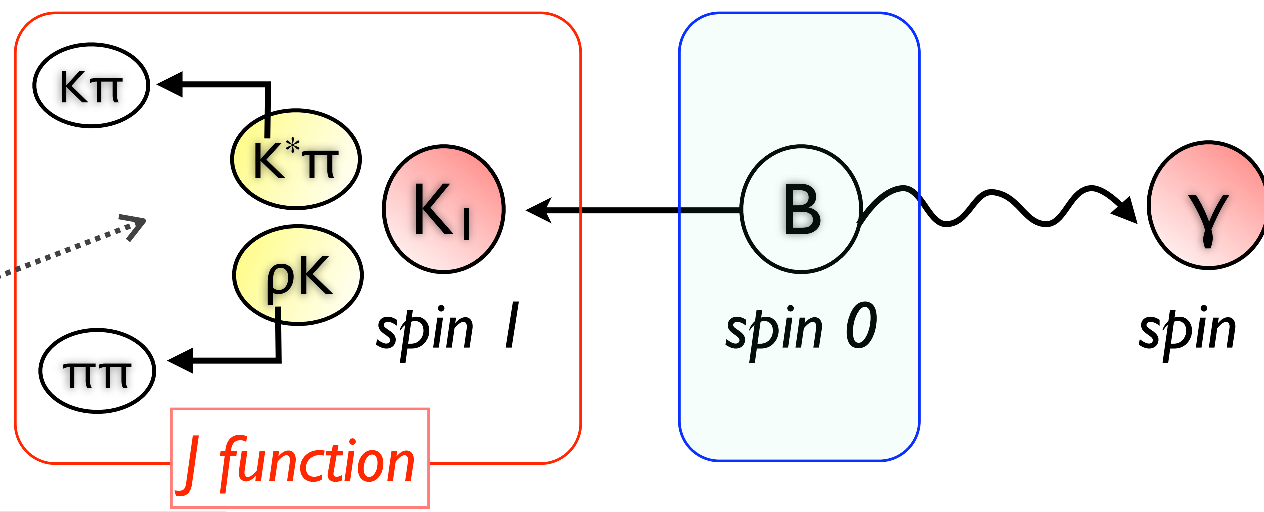
$$= \frac{3}{4} \frac{\langle Im(\hat{n}\cdot(\vec{J}\times\vec{J}^*))\rangle}{\langle|\vec{J}|^2\rangle} \frac{|c_R|^2 - |c_L|^2}{|c_R|^2 + |c_L|^2}$$

A= - 0.085
±0.019(stat)
±0.003(syst)

LHCb-CONF-2013-009

$\vec{J}$: Helicity amplitude of $K_1(1^+)\to K\pi\pi$

λ : Polarization parameter related to C7, C7' etc...



Source of imaginary part : overlap of two Breite-Wigner

Daum et al, Nucl Phys, B187 ('81)
Thesis of S.Akar (Babar)

* Most likely, K_1 can decays through $(K\pi)_S\pi$, too.

Interpreting Up-Down Asymmetry

Gronau, Grossman, Pirjol, Ryd PRL88('01)

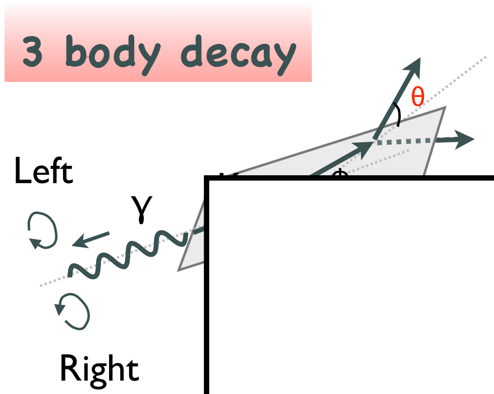
$$\mathcal{A} = \frac{\int_0^1 \cos\theta \frac{d\Gamma}{d\cos\theta} - \int_{-1}^0 \cos\theta \frac{d\Gamma}{d\cos\theta}}{\int_{-1}^1 \cos\theta \frac{d\Gamma}{d\cos\theta}}$$

A= - 0.085

stat)

syst)

3-009



We need detailed information on the hadronic amplitude of $K_1 \rightarrow K\pi\pi$

Angular & Dalitz distribution of K_1 decay ⟺ Circularly-polarization measurement of γ

J function

Source of imaginary part : overlap of two Breite-Wigner

Daum et al, Nucl Phys, B187 ('81)
Thesis of S.Akar (Babar)

* Most likely, K_1 can decays through $(K\pi)_S\pi$, too.

Strong decay of $K_1 \to K\pi\pi$

How to extract the hadronic information (i.e. function J)?

1. Model independent extraction i.e. from data (most ideal)

J. Hebinger, EK, Le Yaouanc, A. Tayduganov, in preparation

$B \to J/\Psi K_1$, $\tau \to K_1 \nu$...

2. Model dependent extraction i.e. theoretical estimate

Modeling J function:

A. Tayduganov, EK, Le Yaouanc PRD '03

Assume $K_1 \to K\pi\pi$ comes from quasi-two-body decay, e.g. $K_1 \to K^*\pi$, $K_1 \to \rho K$, then, J function can be written in terms of:

- 4 form factors (S,D partial wave amplitudes)
- 2 couplings ($g_{K^*K\pi}$, $g_{\rho\pi\pi}$)
- 1 relative phase between two channel

Strong decay of $K_1 \to K\pi\pi$

How to extract the hadronic information (i.e. function J)?

1. Model independent extraction i.e. from data (most ideal)

tion

2. M

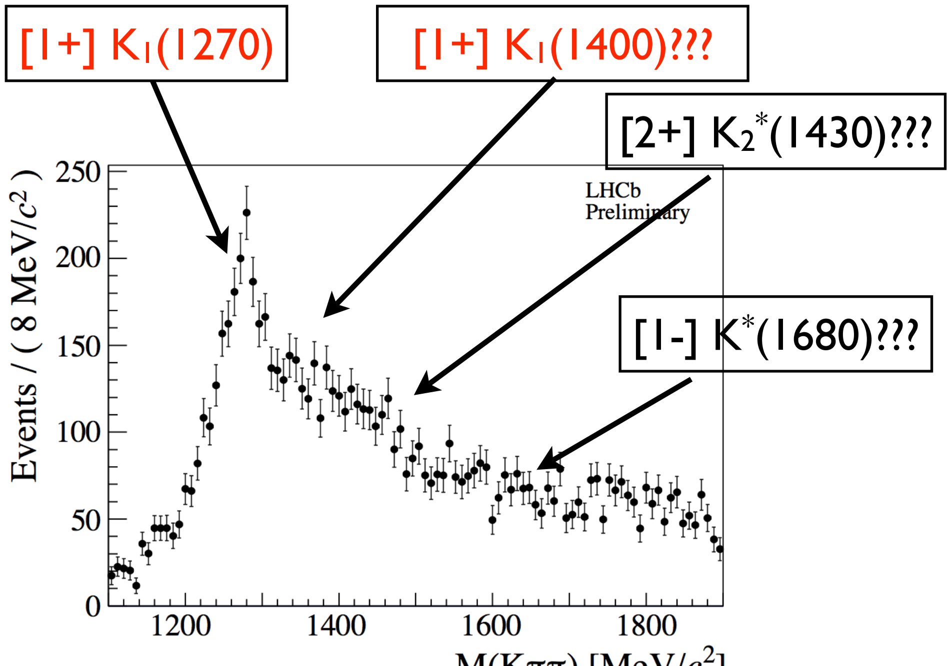
M

Simultaneous fit of B->J/psi K1 & B-> K1 gamma

$$\mathcal{A} = \frac{\int_0^{\pi/2} d|\mathcal{M}|^2 d\theta - \int_{\pi/2}^{\pi} d|\mathcal{M}|^2 d\theta}{\int_0^{\pi} d|\mathcal{M}|^2 d\theta} = \frac{3}{4} \frac{\langle Im(\hat{n}\cdot(\vec{J}\times\vec{J}^*))\rangle}{\langle|\vec{J}|^2\rangle} \frac{|c_R|^2 - |c_L|^2}{|c_R|^2 + |c_L|^2}$$

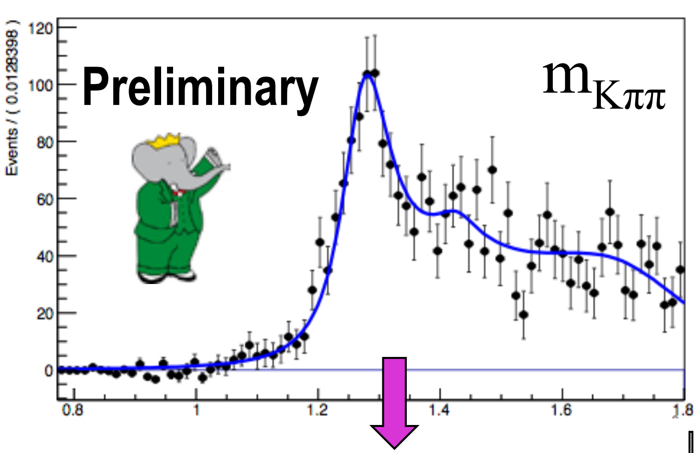
- 4 form factors (S,D partial wave amplitudes)
- 2 couplings ($g_{K^*K\pi}$, $g_{\rho\pi\pi}$)
- 1 relative phase between two channel

Observed K_1 shape



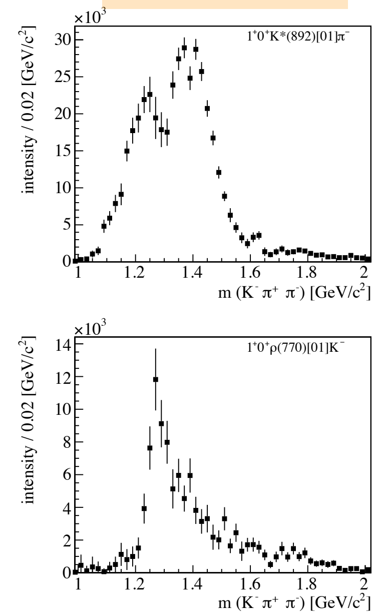
LHCb-CONF-2013-009

Babar '14

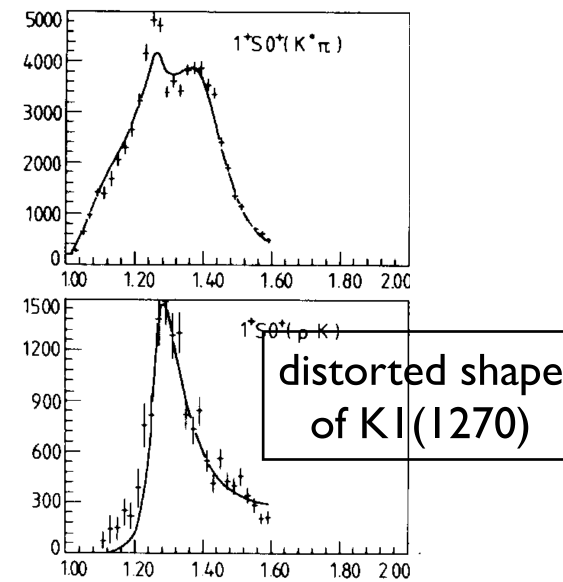


$A(K_{res} \to K\pi\pi)$

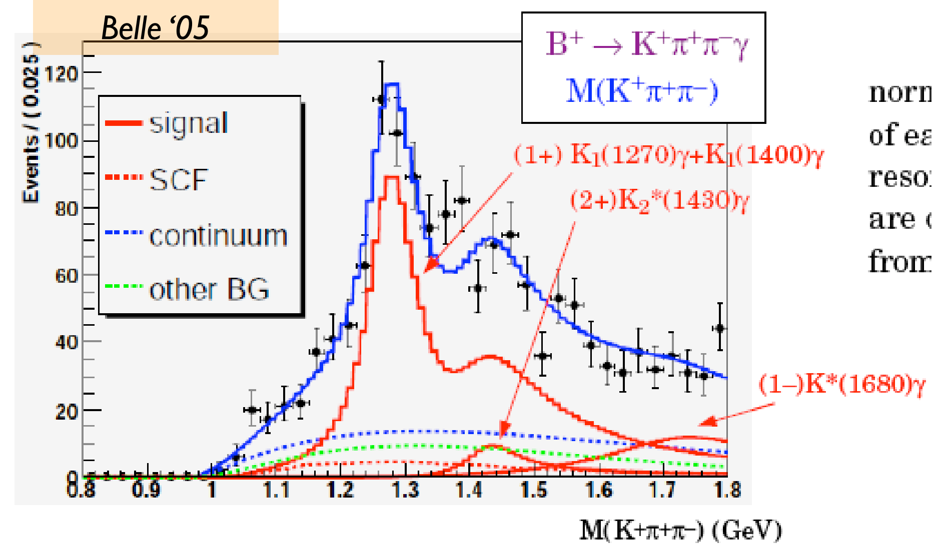
COMPASS '12



ACMMOR '81

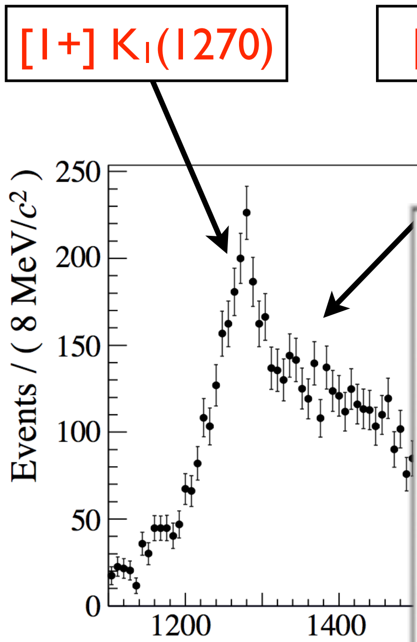


Belle '05



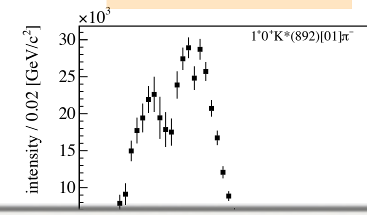
Talk by S.Nishida at CKM2008

Observed K_1 shape

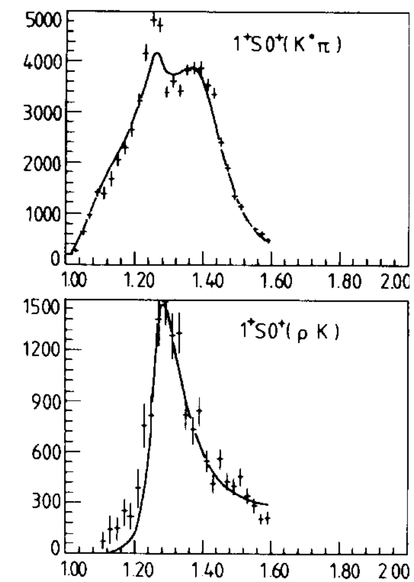


LHCb-CONF-2013-009

COMPASS '12

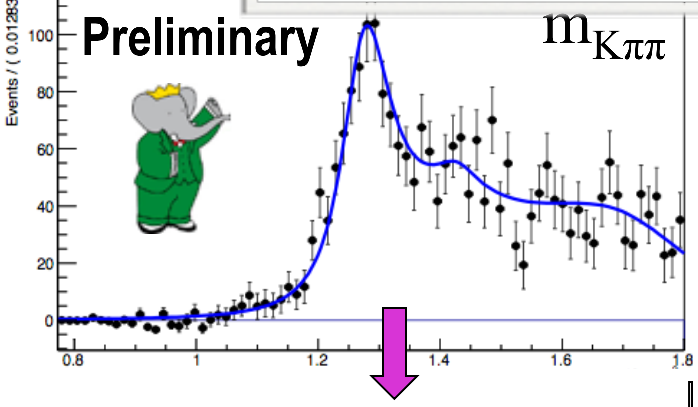


ACMMOR '81

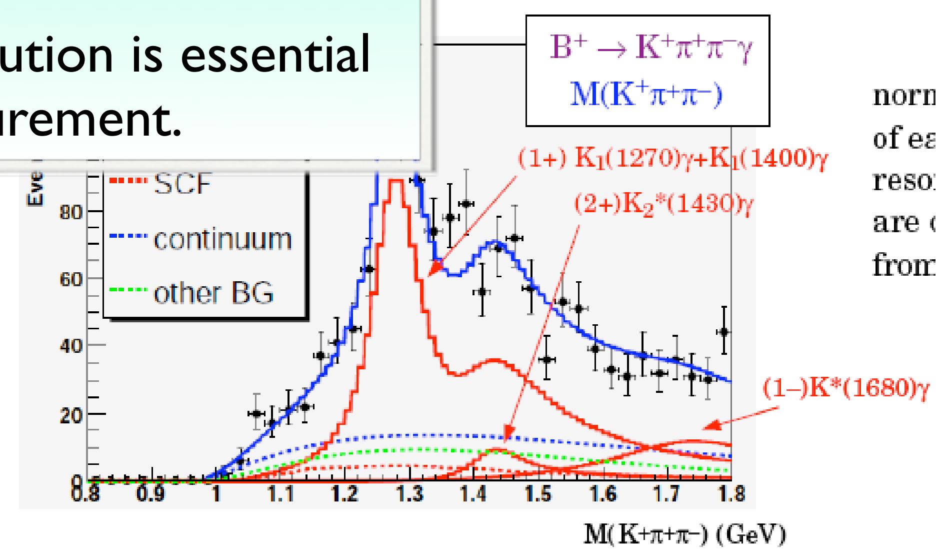


- ✓The shape is obviously not Breit-Wigner type (I will explain why it is so and how we can deal with this).
- ✓Then, using the Breit-Wigner may lead to a wrong conclusions when we want to estimate the production rate of K1(1270) and K1(1400).
- ✓Estimate of K1(1400) pollution is essential for the polarization measurement.

Babar '14



$A(K_{res} \to K\pi\pi)$



Talk by S.Nishida at CKM2008

Example of Babar

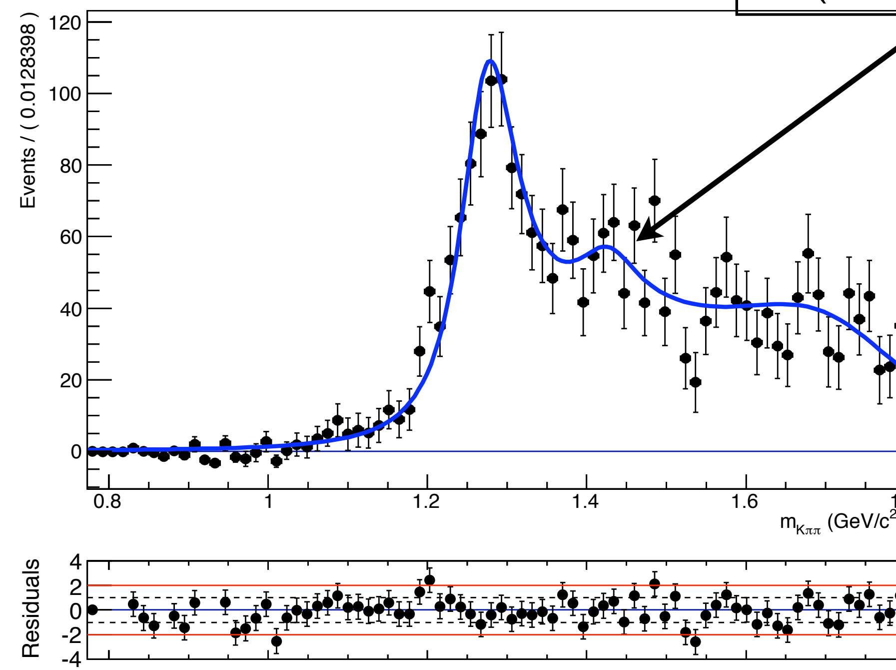
$$|A(m;c_j)|^2 = \sum_J \left| \sum_j c_j \, \mathrm{BW}_j^J(m) \right|^2 \Bigg|_{m=m_{K\pi\pi}} ,$$

$$\mathrm{BW}_j^J(m) = \frac{1}{(m_j^0)^2 - m^2 - i m_j^0 \Gamma_j^0} \Bigg|_{m=m_{K\pi\pi}} ,$$

$$c_j = \alpha_j \, e^{i\phi_j} .$$

J^P	$K_{\rm res}$	Mass m_j^0 (MeV/c^2)	Width Γ_j^0 (MeV/c^2)
1^+	$K_1(1270)$	1272 ± 7	90 ± 20
	$K_1(1400)$	1403 ± 7	174 ± 13
1^-	$K^*(1410)$	1414 ± 15	232 ± 21
	$K^*(1680)$	1717 ± 27	322 ± 110
2^+	$K_2^*(1430)$	1425.6 ± 1.5	98.5 ± 2.7

K*(1410)+K$_2$*(1430)???



J^P	Kres	Magnitude α	Phase ϕ (rad.)	Fit fraction
1^+	$K_1(1270)$	1.0 (fixed)	0.0 (fixed)	$0.61^{+0.08}_{-0.05}$(stat.)$^{+0.05}_{-0.05}$(syst.)
	$K_1(1400)$	0.71 ± 0.10(stat.)$^{+0.12}_{-0.08}$(syst.)	2.97 ± 0.17(stat.)$^{+0.11}_{-0.12}$(syst.)	$0.17^{+0.08}_{-0.05}$(stat.)$^{+0.05}_{-0.03}$(syst.)
1^-	$K^*(1410)$	1.25 ± 0.16(stat.)$^{+0.18}_{-0.13}$(syst.)	3.15 ± 0.12(stat.)$^{+0.03}_{-0.02}$(syst.)	$0.37^{+0.08}_{-0.07}$(stat.)$^{+0.06}_{-0.02}$(syst.)
	$K^*(1680)$	2.02 ± 0.28(stat.)$^{+0.32}_{-0.21}$(syst.)	0.0 (fixed)	$0.43^{+0.05}_{-0.04}$(stat.)$^{+0.09}_{-0.06}$(syst.)
2^+	$K_2^*(1430)$	0.33 ± 0.09(stat.)$^{+0.07}_{-0.14}$(syst.)	0.0 (fixed)	$0.06^{+0.04}_{-0.03}$(stat.)$^{+0.04}_{-0.05}$(syst.)
Sum of fit fractions				$1.64^{+0.18}_{-0.14}$(stat.)$^{+0.14}_{-0.07}$(syst.)
Interferences		$J^P = 1^+ : \{K_1(1270) - K_1(1400)\}$		$-0.35^{+0.10}_{-0.16}$(stat.)$^{+0.05}_{-0.06}$(syst.)
		$J^P = 1^- : \{K^*(1410) - K^*(1680)\}$		$-0.29^{+0.08}_{-0.11}$(stat.)$^{+0.06}_{-0.12}$(syst.)

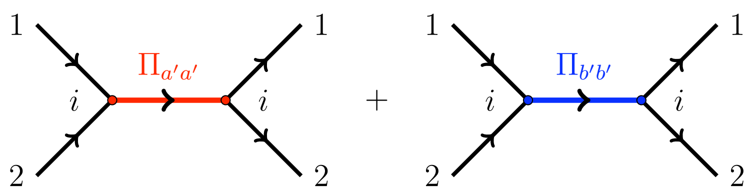
Thesis of S. Akar

Daum's formalism - K-matrix -

K-matrix formalism

- *Two resonances decaying to one channel*

Consider again an elastic scattering at mass m, but suppose that there exi
resonances with masses $m_{a'}$ and $m_{b'}$ coupling to channel i:



In this case the K-matrix is

$$K = \frac{f_{a'i}^2}{m_{a'} - m} + \frac{f_{b'i}^2}{m_{b'} - m}$$

Thus, the transition amplitude is given by

$$T = \frac{f_{a'i}^2}{m_{a'} - m - i\frac{\Gamma_{a'}(m)}{2} - i\frac{\Gamma_{b'}(m)}{2}\frac{m_{a'}-m}{m_{b'}-m}} + \frac{f_{b'i}^2}{m_{b'} - m - i\frac{\Gamma_{b'}(m)}{2} - i\frac{\Gamma_{a'}(m)}{2}\frac{m_{b'}-m}{m_{a'}-m}}$$

$$\Gamma_{a'i}(m) = 2f_{a'i}^2\rho_{ii}(m)$$ Partial width (final state=i)

$$\Gamma_{a'}(m) = \sum_i \Gamma_{a'i}(m)$$ Total width

- *Similar to Breit-Wigner but the width part is sum of partial widths.*
- *Thus, the mass and the width in the K-matrix formalism depend on the energy different from Breit-Wigner form.*

ρ_{ij} is the phase space factor.
This shows that when, the phase space is limited for a given channel, we see the distortion in the total decay width.