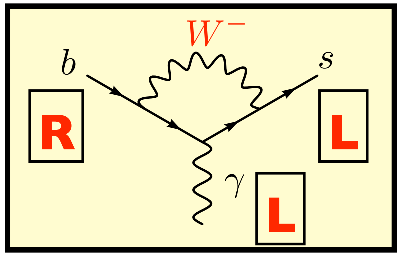
Theoretical interests on measuring C_7'

Emi KOU (LAL/IN2P3-Orsay)
in collaboration with D.Becirevic,A.Tayduganov&A.LeYaouanc

Workshop on the physics reach
of rare and exclusive B decays
Sussex University
10th-11th September 2012

The b→sll at low q^2



- At the limit of $q^2=0$, the b→sll process approaches to b→sγ→sll.

$$\bar{b}A_\mu s = -iV_{tb}V_{ts}^*\frac{G_F}{\sqrt{2}}\frac{e}{8\pi^2}\Big[\underbrace{E_0(x_t)\bar{s}_L(q^2\gamma_\mu - q_\mu \not{q})b_L}_{O_{9\sim 10}:\ \text{penguin operator}} - \underbrace{m_b E_0'(x_t)\bar{s}_L\sigma_{\mu\nu}q^\nu b_R}_{O_{7\gamma,8g}:\ \text{magnetic operator}}\Big]$$

photon off-shell
= not polarized
(e.g. semi-leptonic)

photon on-shell
and $b_R \to s_L\, \gamma_L$,

- Thus, the interest at low q^2 is the c_7&c_7' measurement.
- A clean observable proposed:

Kruger, Matias PRD71
Becirevic, Schneider, NPB854

$$\lim_{q^2\to 0}\mathcal{A}_T^{(2)}(q^2) = \frac{2\mathcal{R}e[C_{7\gamma}C_{7\gamma}'^*]}{|C_{7\gamma}|^2+|C_{7\gamma}'|^2}$$

$$\lim_{q^2\to 0}\mathcal{A}_T^{(\mathrm{im})}(q^2) = \frac{2\mathcal{I}m[C_{7\gamma}C_{7\gamma}'^*]}{|C_{7\gamma}|^2+|C_{7\gamma}'|^2}$$

Observables at low q^2 ($A_T^{(2)}$ and $A_T^{(im)}$)

- $A_T^{(2)}$ and $A_T^{(im)}$ are written in terms of transverse amplitudes:

$$\boxed{\mathcal{A}_T^{(2)}(q^2) = \frac{I_3(q^2)}{2I_2^s(q^2)}} \qquad \boxed{\mathcal{A}_T^{(\mathrm{im})}(q^2) = \frac{I_9(q^2)}{2I_2^s(q^2)}}$$

$$I_2^s(q^2) = \frac{\beta_\ell^2}{4}\left[|A_\perp^{\ell_L}|^2 + |A_\perp^{\ell_R}|^2 + |A_\parallel^{\ell_L}|^2 + |A_\parallel^{\ell_R}|^2\right],$$

$$I_3(q^2) = \frac{\beta_\ell^2}{2}\left[|A_\perp^{\ell_L}|^2 + |A_\perp^{\ell_R}|^2 - |A_\parallel^{\ell_L}|^2 - |A_\parallel^{\ell_R}|^2\right],$$

$$I_6^s(q^2) = 2\beta_\ell \mathcal{R}e\left[A_\parallel^{\ell_L} A_\perp^{\ell_L *} - A_\parallel^{\ell_R} A_\perp^{\ell_R *}\right],$$

$$I_9(q^2) = \beta_\ell^2 \mathcal{I}m\left[A_\perp^{\ell_L} A_\parallel^{\ell_L *} + A_\perp^{\ell_R} A_\parallel^{\ell_R *}\right].$$

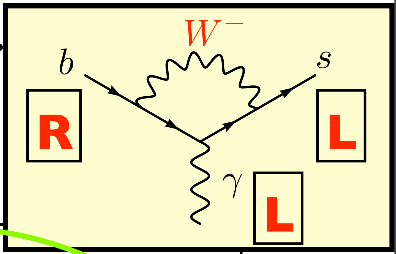
Kruger, Matias PRD71
Becirevic, Schneider, NPB854
Egede et al. JHEP0811

$$\boxed{\lim_{q^2\to 0} \mathcal{A}_T^{(2)}(q^2) = \frac{2\mathcal{R}e[C_{7\gamma}C_{7\gamma}'^{*}]}{|C_{7\gamma}|^2 + |C_{7\gamma}'|^2}} \qquad \boxed{\lim_{q^2\to 0} \mathcal{A}_T^{(\mathrm{im})}(q^2) = \frac{2\mathcal{I}m[C_{7\gamma}C_{7\gamma}'^{*}]}{|C_{7\gamma}|^2 + |C_{7\gamma}'|^2}}$$

* We will come back to the issue of $\Delta q^2 \neq 0$ effect later

New physics sensitive to $A_T^{(2)}$ and $A_T^{(im)}$

- New physics contributions to c_7&c_7' here are the same one we can extract from the b→sγ induced processes.



- The O_7 has a particular structure in SM

$$\bar{b}A_\mu s = -iV_{tb}V_{ts}^*\frac{G_F}{\sqrt{2}}\frac{e}{8\pi^2}\left[\underbrace{E_0(x_t)\bar{s}_L(q^2\gamma_\mu - q_\mu \not{q})b_L}_{O_{9\sim10}:\ \text{penguin operator}} - \underbrace{m_b E_0'(x_t)\bar{s}_L\sigma_{\mu\nu}q^\nu b_R}_{O_{7\gamma,8g}:\ \text{magnetic operator}}\right]$$

photon off-shell
= not polarized
(e.g. semi-leptonic)

photon on-shell
and $b_R \to s_L\, \gamma_L$,

W-boson couples only left-handed ⟺ γ of b →s γ should be circularly-polarized

b →s γ_L (left-handed polarization)

b →s γ_R (right-handed polarization)

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

Opposite chirality is suppressed by a factor m_s/m_b

New physics sensitive to $A_T^{(2)}$ and $A_T^{(im)}$

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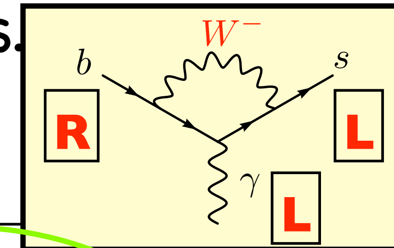


$$\bar{b}A_\mu s = -iV_{tb}V_{ts}^*\frac{G_F}{\sqrt{2}}\frac{e}{8\pi^2}\Big[\underbrace{E_0(x_t)\bar{s}_L(q^2\gamma_\mu - q_\mu \not{q})b_L}_{O_{9\sim10}:\ \text{penguin operator}} - \underbrace{m_b E_0'(x_t)\bar{s}_L\sigma_{\mu\nu}q^\nu b_R}_{O_{7\gamma,8g}:\ \text{magnetic operator}}\Big]$$

photon off-shell

photon on-shell

$_R \to s_L\ \gamma_L$,

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

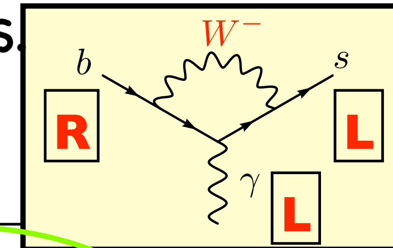
- b →s γ_L (left-handed polarization)
- b →s γ_R (right-handed polarization)

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

Opposite chirality is suppressed by a factor m_s/m_b

New physics sensitive to $A_T^{(2)}$ and $A_T^{(im)}$

- New physics contributions to c_7&c_7' here are the same one we can extract from the $b \to s\gamma$ induced processes.



- The O_7 has a particular structure in SM

$$\bar{b}A_\mu s = -iV_{tb}V_{ts}^* \frac{G_F}{\sqrt{2}} \frac{e}{8\pi^2} \left[\underbrace{E_0(x_t)\bar{s}_L(q^2\gamma_\mu - q_\mu \not{q})b_L}_{O_{9\sim10}:\ \text{penguin operator}} - \underbrace{m_b E_0'(x_t)\bar{s}_L\sigma_{\mu\nu}q^\nu b_R}_{O_{7\gamma,8g}:\ \text{magnetic operator}} \right]$$

photon off-shell

photon on-shell

$R \to s_L \gamma_L$,

However, this left-handedness of the

polar

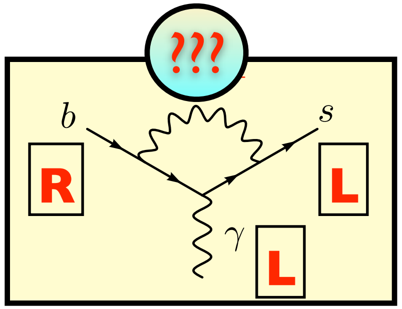
confi

$A_T^{(2)}$ and $A_T^{(im)}$ are indeed sensitive to the right-handed contribution.

$$\lim_{q^2\to 0} \mathcal{A}_T^{(2)}(q^2) = \frac{2\mathcal{R}e[C_{7\gamma}C_{7\gamma}'^*]}{|C_{7\gamma}|^2 + |C_{7\gamma}'|^2}$$

$$\lim_{q^2\to 0} \mathcal{A}_T^{(im)}(q^2) = \frac{2\mathcal{I}m[C_{7\gamma}C_{7\gamma}'^*]}{|C_{7\gamma}|^2 + |C_{7\gamma}'|^2}$$

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.

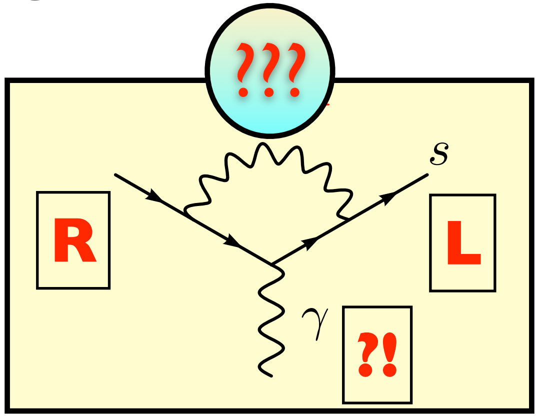
Left-Right symmetric model (W_R)	SUSY GUT model δ_{RR} mass insertion
Blanke et al. JHEP1203	*Girrbach et al. JHEP1106*

- Which flavour structure?
  The models that contain new particles which change the chirality inside of the $b \to s\gamma$ loop can induce a large chiral enhancement!

Left-Right symmetric model: m_t/m_b	SUSY with δ_{RL} mass insertions: m_{SUSY}/m_b
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.

Theoretical interests in searching right-handed current using b→sγ



- Left-Right symmetry is often required for building new physics models in order to satisfy the electroweak data of rho≃1.
- SUSY-GUT models often induces right-handed current in relation to the right-handed neutrino.
- etc...
- In addition, when there is a new particle in the loop which changes the chirality inside of the loop, there is chiral enhancement!

examples

Left-Right symmetric model: mt/mb

Babu, Fujikawa, Yamada PLB333 '94

SUSY with δ_{RL} mass insertions: m_{SUSY}/mb

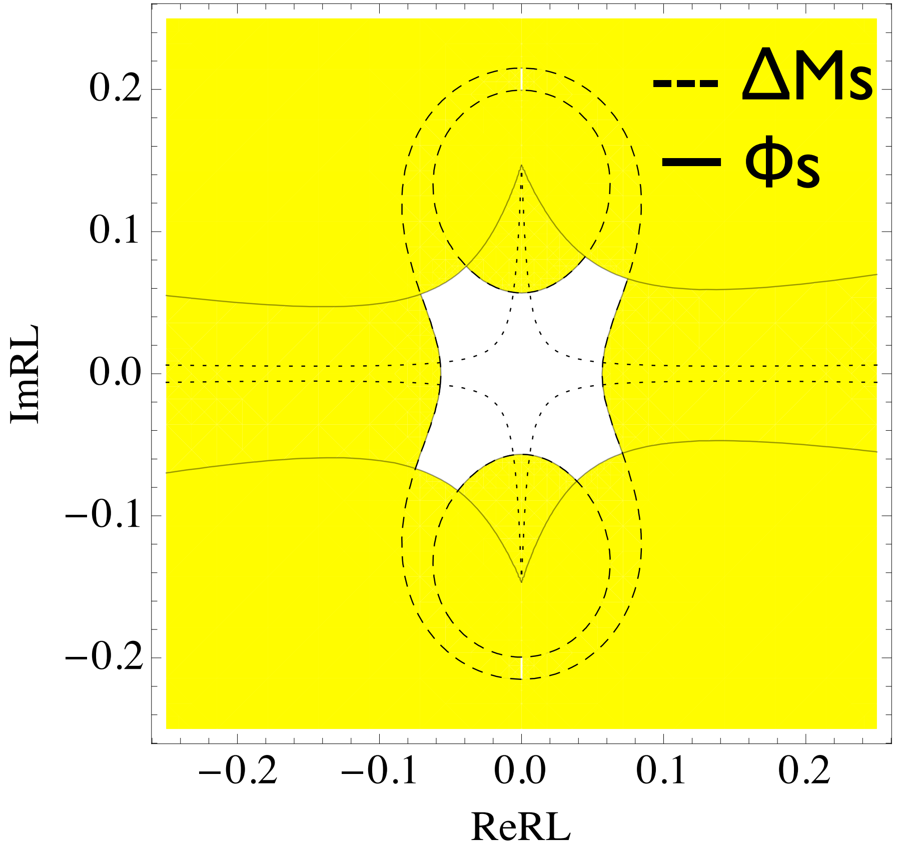
Gabbiani, Gabrielli, Masiero, Silvestrini NPB477 '96

We can allow a large new physics enhancement in b→sγ/b →sg (on-shell s/g), despite of the strong constraints on e.g. Bs box diagram, namely ΔM_s and Φ_s.

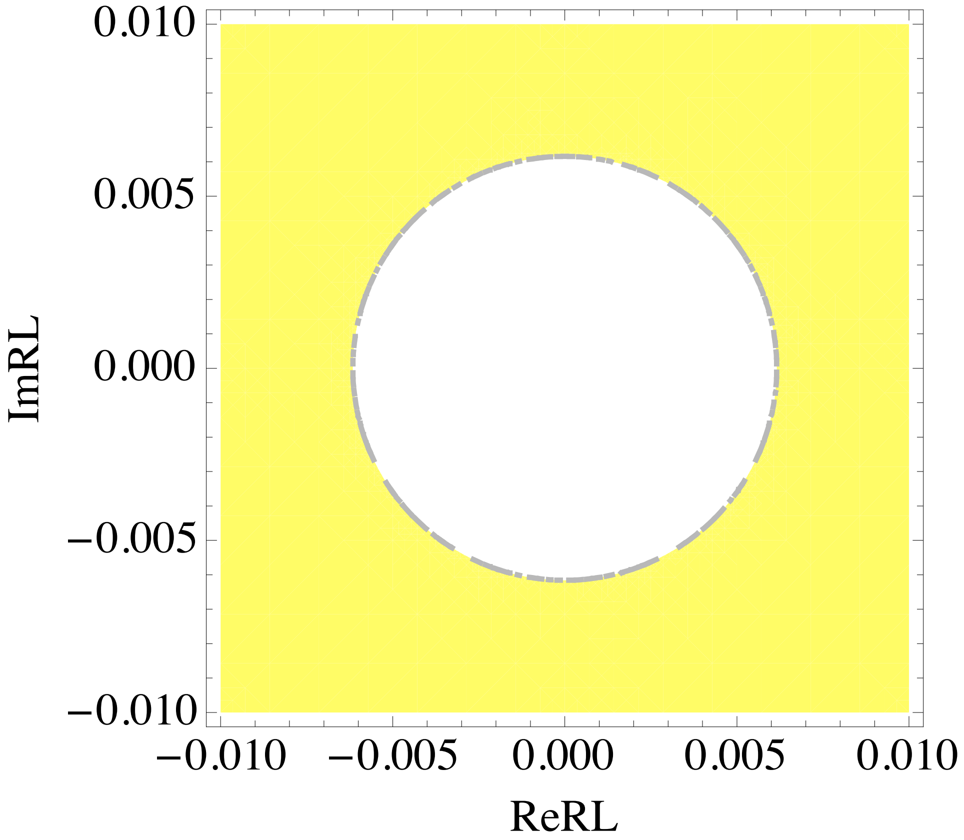
Ball, EK, Khalil, PRD69 '04

Example of chiral enhancement:
=SUSY with δ_{RL} mass insertions=

- Constraints from Bs mixing parameters (DMs and phis):



- Constraints from $B \to X_s \gamma$ branching ratios:



Current constraints on C_7&C_7'

We can write the amplitude including RH contribution as:

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

- Constraints from inclusive branching ratio

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

HFAG $(3.43 \pm 0.21 \pm 0.07)\times10^{-4}$

- Constraints from Time dependent CPV of $S_{K_S\pi^0\gamma}$

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

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

Current constraints on C_7&C_7'

We can write the amplitude including RH contribution as:

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

In principle, C_7&C_7' can be complex number, so we have four parameters to constrain.

- Constraints from inclusive branching ratio

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

HFAG $(3.43 \pm 0.21 \pm 0.07)\times 10^{-4}$

- Constraints from Time dependent CPV of $S_{K_S\pi^0\gamma}$

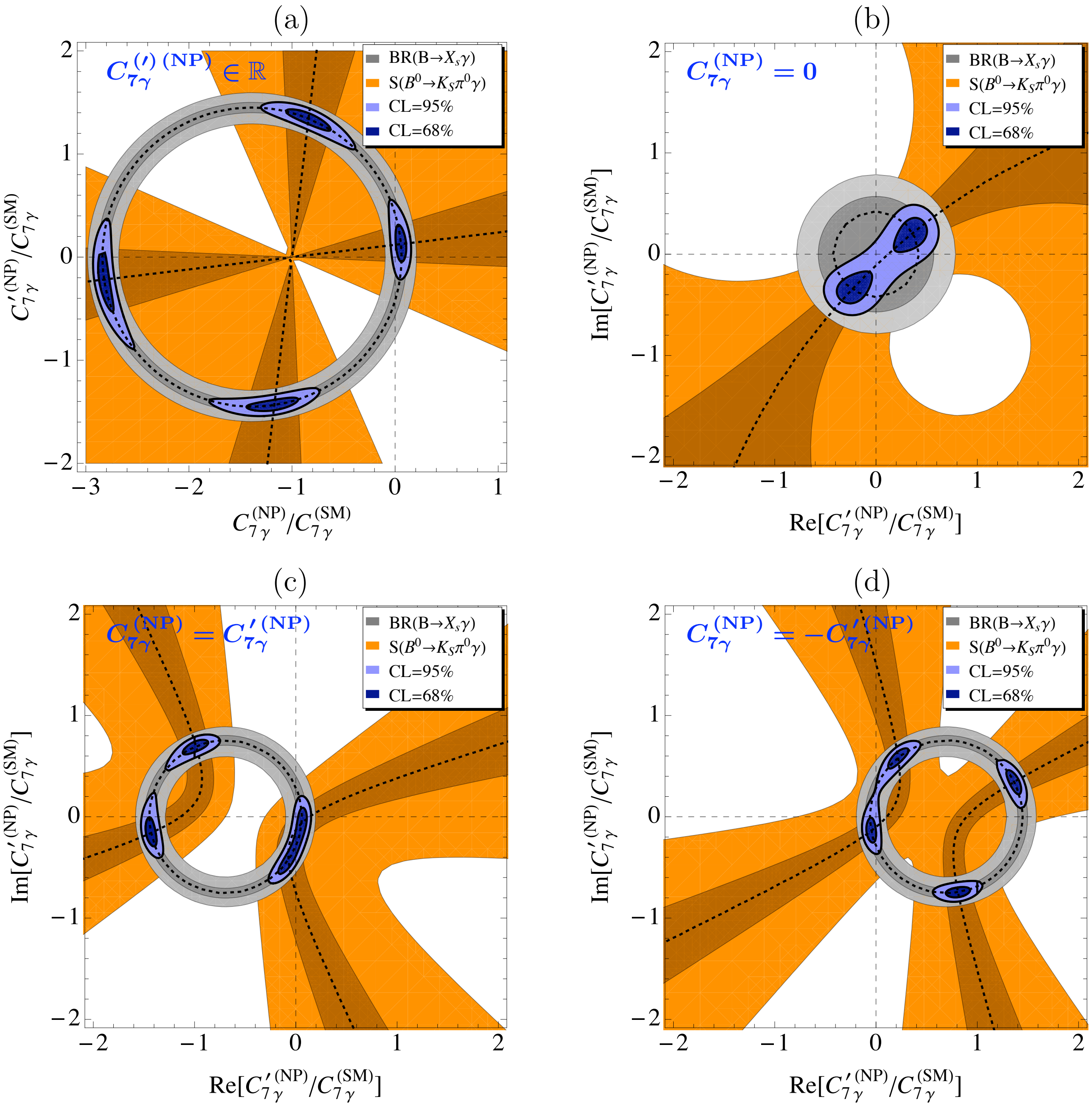
$$S_{K_S\pi^0\gamma} = \frac{2|C_{7\gamma}^{\rm SM} C_{7\gamma}'^{\rm NP}|}{|C_{7\gamma}^{\rm SM}|^2 + |C_{7\gamma}'^{\rm NP}|^2}\sin(2\phi_1 - \phi_R) \qquad \phi_R = \arg\left[\frac{C_{7\gamma}'^{\rm NP}}{C_{7\gamma}^{\rm SM}}\right]$$

HFAG $S_{K_S\pi^0\gamma} = -0.16 \pm 0.22$

Current constraints on C_7&C_7'

New physics real

New physics only RH C_7'



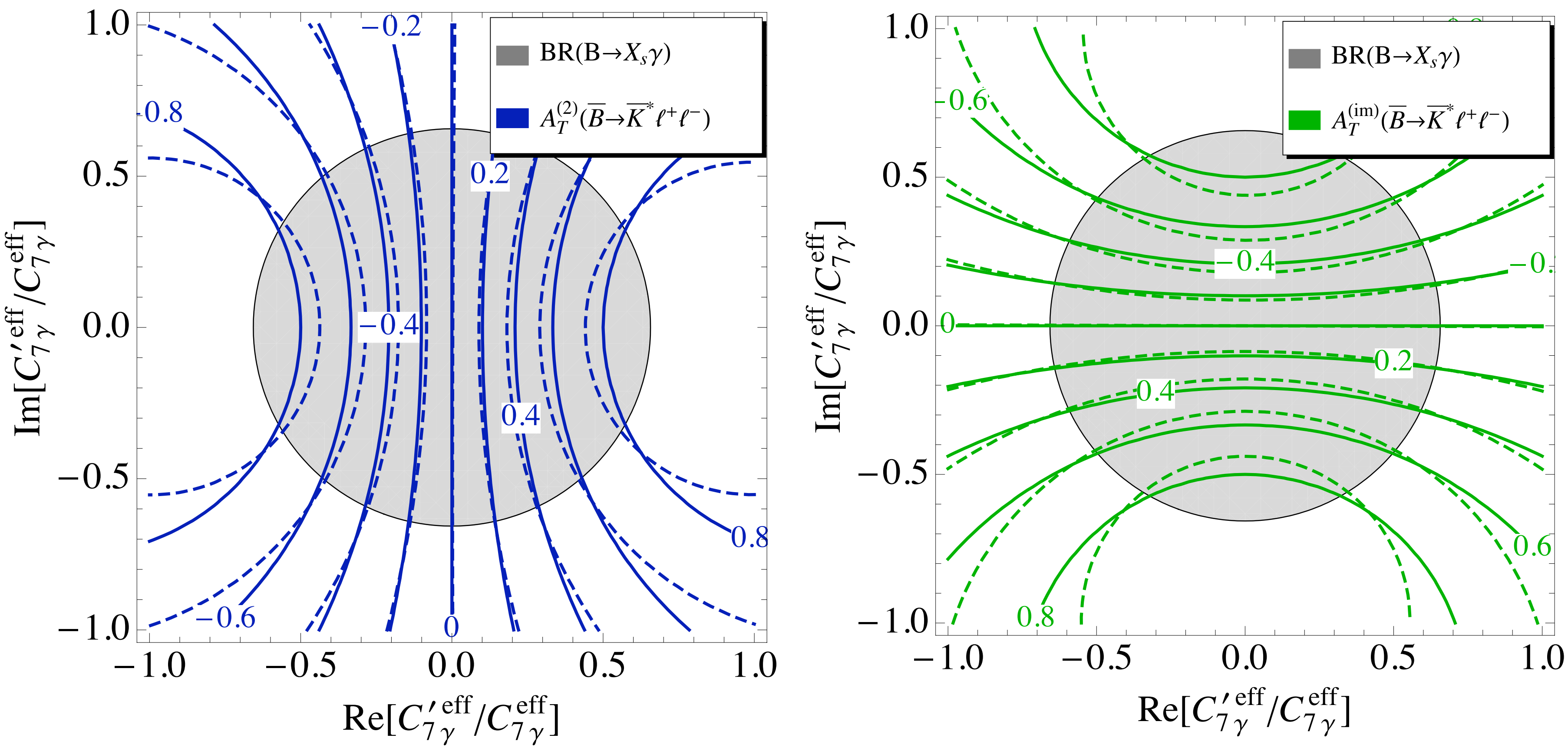
New physics LH=RH

New physics LH=-RH

Constraint expectation from $A_T^{(2)}$ and $A_T^{(im)}$

Becirevic, EK, Le Yaouanc, Tayduganov arXive:1206.1502

Scenario (b): New physics with only RH (C_7^{NP}=0)
Expected constraint from
$A_T^{(2)}$, $A_T^{(im)}$ measurement with 10% precision



C_9&C_{10} assumed to be SM. The q^2 dependence (dashed) small

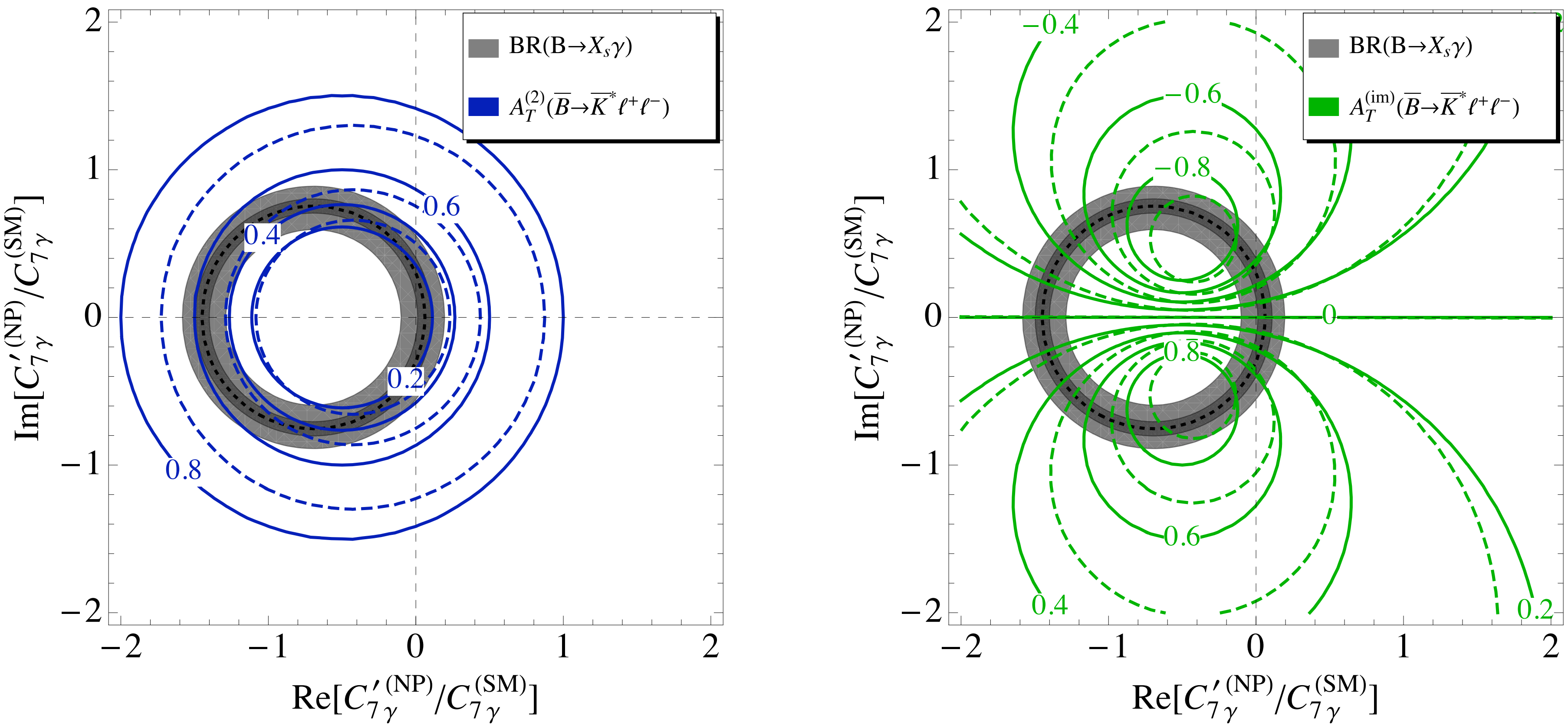
Constraint expectation from $A_T^{(2)}$ and $A_T^{(im)}$

Becirevic, EK, Le Yaouanc, Tayduganov arXive:1206.1502

Scenario (c): New physics with LR=RH ($C_7^{NP}=C_7'^{NP}$)

Expected constraint from

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



C_9&C_{10} assumed to be SM. The q^2 dependence (dashed) large

Comparison of the three methods

Becirevic, EK, Le Yaouanc, Tayduganov arXive:1206.1502

proposed methods

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

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

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

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

- **Method III**: $B \to K_1(\to K\pi\pi)\gamma$ (called λ_γ) EK, Le Yaouanc, A.Tayduganov, PRD83 ('11)

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

Comparison of the three methods

Becirevic, EK, Le Yaouanc, Tayduganov arXive:1206.1502

proposed methods

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

$$S_{K_S\pi^0\gamma} = \frac{2|C_{7\gamma}^{SM}\ldots}{|C_{7\gamma}^{SM}|^2 + \ldots} \qquad \varphi_R = \arg\left[\frac{C_{7\gamma}^{\prime NP}}{C_{7\gamma}^{SM}}\right]$$

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

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

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

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

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

Super Flavour Factory/LHCb
$\sigma_\lambda(0.1\text{-}0.2)$

New physics
only RH C_7'

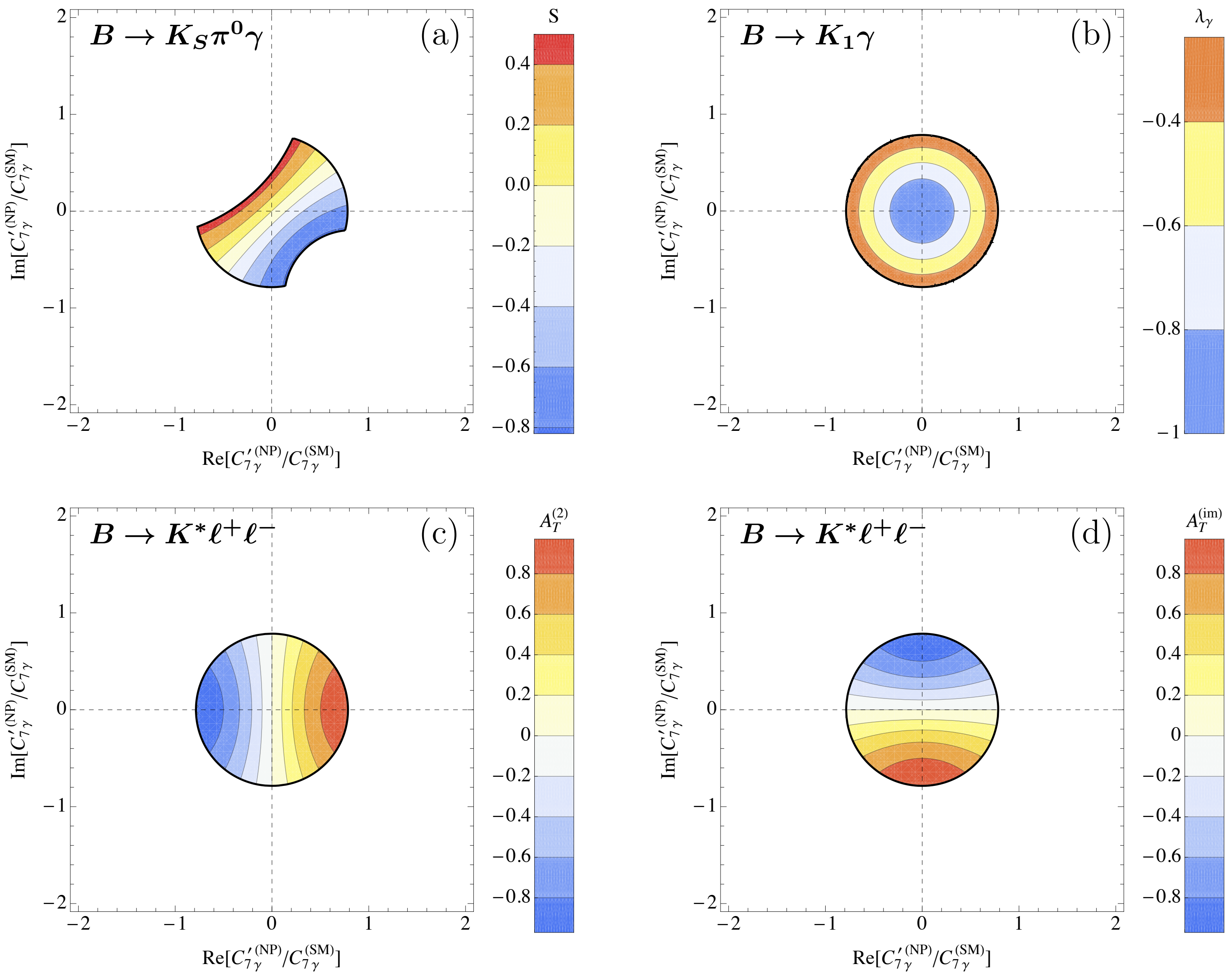


Figure 5: Prospect of the future constraints on $C_{7\gamma}^{(\prime)}$ in the NP scenario *II*: $C_{7\gamma}^{(\mathrm{NP})}$ is purely SM-like, i.e. $C_{7\gamma}^{(\mathrm{NP})} = 0$. The contour colours in Fig. (a, b, c, d) correspond respectively to $S_{K_S\pi^0\gamma}$, λ_γ, $\mathcal{A}_T^{(2)}(0)$ and $\mathcal{A}_T^{(\mathrm{im})}(0)$ allowed by a $\pm 3\sigma$ error to the central value of $\mathcal{B}^{\mathrm{exp}}(B \to X_s\gamma)$.

New physics
only RH=LF

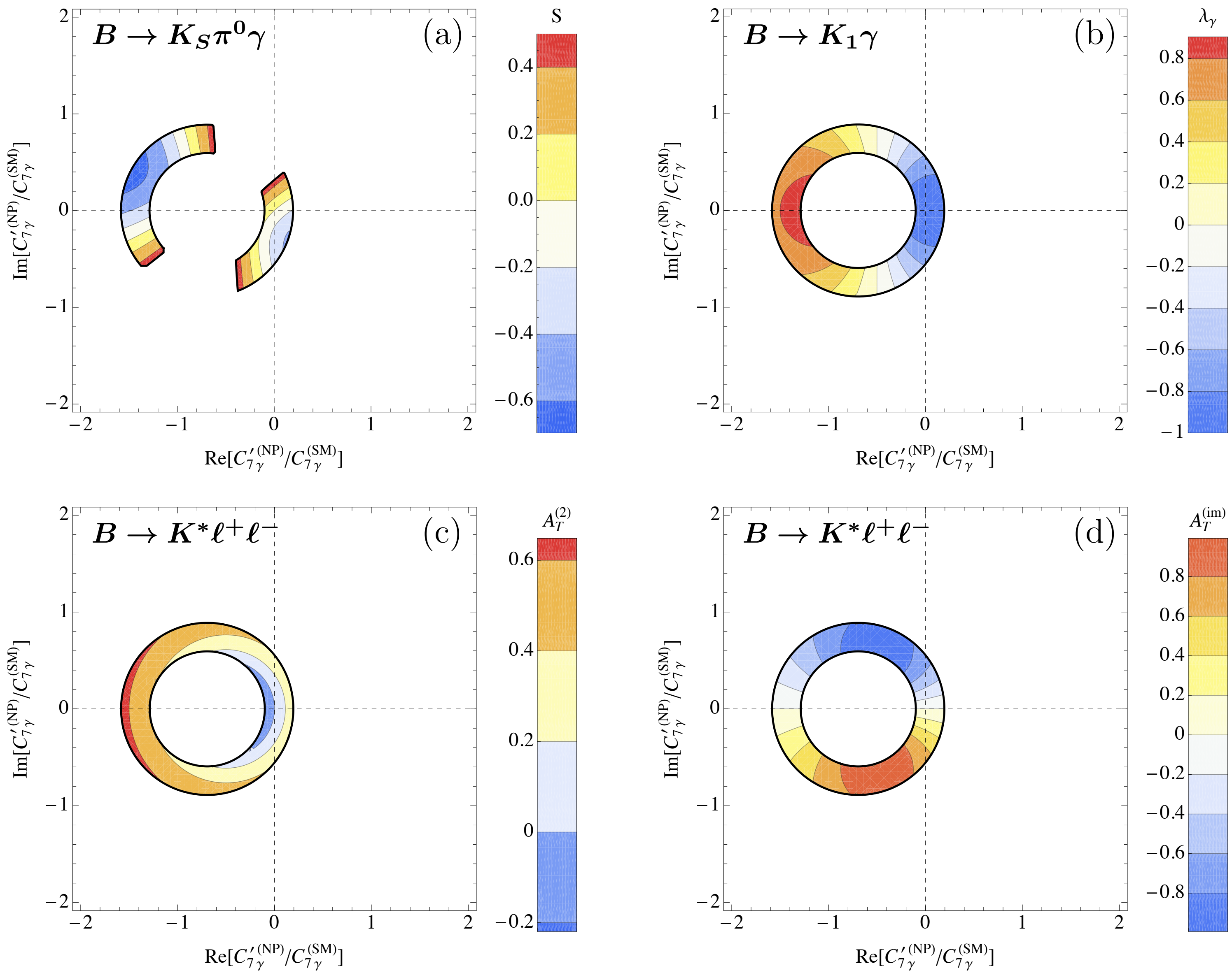


Figure 6: Prospect of the future constraints on $C_{7\gamma}^{(\prime)}$ in the NP scenario *III*: $C_{7\gamma}^{(\mathrm{NP})} = C_{7\gamma}^{\prime\,(\mathrm{NP})}$. The contour colours in Fig. (a, b, c, d) correspond respectively to $S_{K_S\pi^0\gamma}$, λ_γ, $\mathcal{A}_T^{(2)}(0)$ and $\mathcal{A}_T^{(\mathrm{im})}(0)$ allowed by a $\pm 3\sigma$ error to the central value of $\mathcal{B}^{\mathrm{exp}}(B \to X_s\gamma)$.

Summary

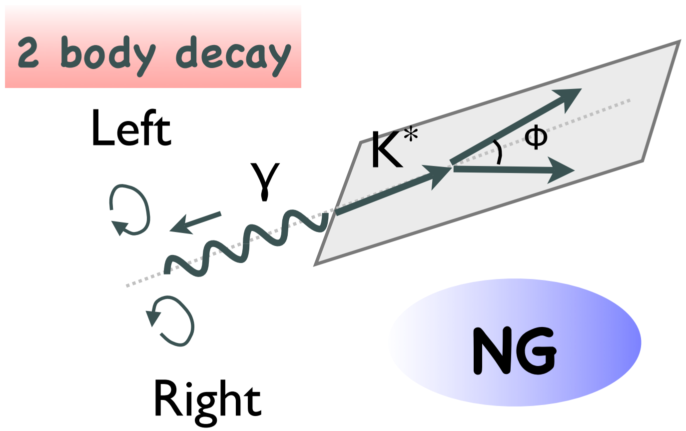
- We discussed the transverse asymmetries of $B_d \rightarrow K^* l^+ l^-$ at low q^2, namely $A_T^{(2)}$, $A_T^{(im)}$.
- The new physics contributions sensitive to $A_T^{(2)}$, $A_T^{(im)}$ at $q^2=0$ are those sensitive to other $b \rightarrow s\gamma$ observables (C_7&C_7').
- I showed a comparison of the three methods to extract C_7&C_7'.
- Advantage of $A_T^{(2)}$, $A_T^{(im)}$ is that they are related to the first order in terms of the $|C_7'/C_7|$.
- Disadvantage of $A_T^{(2)}$, $A_T^{(im)}$, we need assumption for C_9&C_{10} for $q^2 \neq 0$ to constrain $|C_7'/C_7|$.
- The best would be to use different methods and measure C_7&C_7' independently.

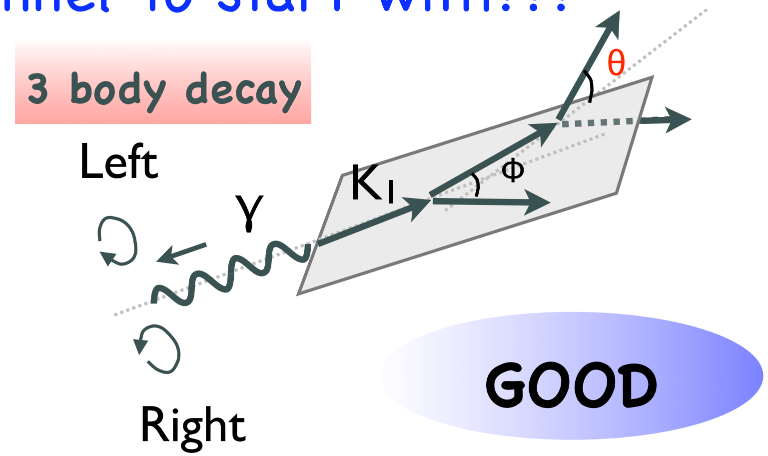
Backup

Polarization measurement using $B \rightarrow K_1(\rightarrow K\pi\pi)\gamma$: the method by Gronau et al.

Gronau, Grossman, Pirjol, Ryd hep-ph/0107254

Why do we need three body channel to start with???





Decays are symmetric along the helicity axis. No LR distinction!

Three body decays can make an angle to the plane!

Polarization measurement using $B \to K_1(\to K\pi\pi)\gamma$: the method by Gronau et al.

Gronau, Grossman, Pirjol, Ryd hep-ph/0107254

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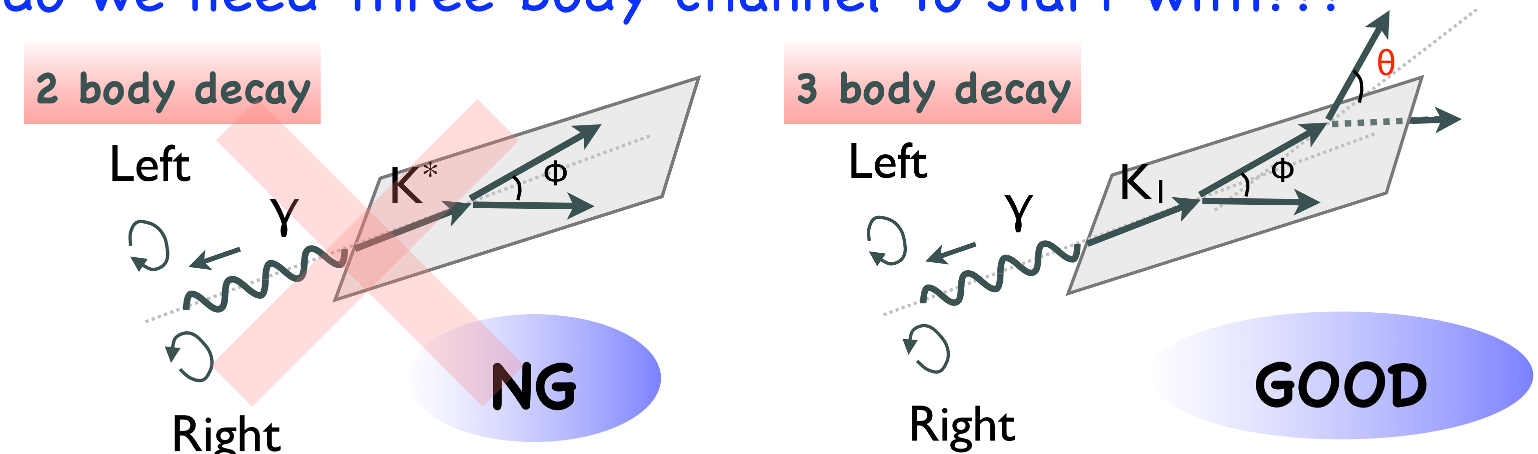

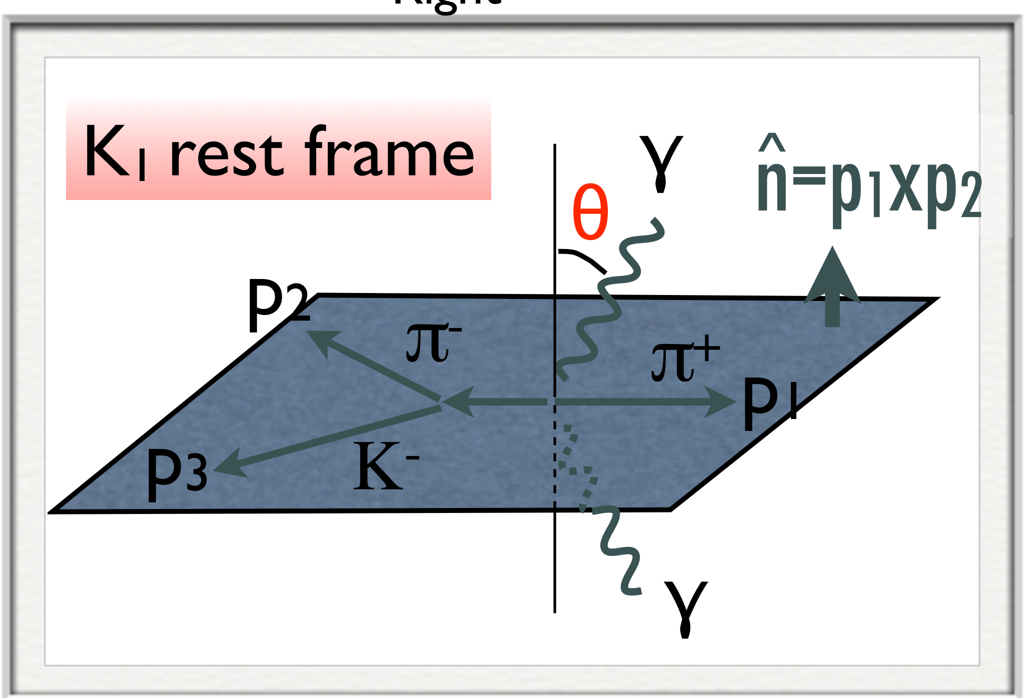

Up-Down asymmetry

Count the number of events with photon above/below the K_1 decay plane and subtract them.

$$\mathcal{A} = \frac{\int_0^{\pi/2} d|\mathcal{M}|^2 d\theta - \int_{\pi/2}^{\pi} d|\mathcal{M}|^2 d\theta}{\int_0^{\pi} d|\mathcal{M}|^2 d\theta}$$

Polarization measurement using $B \to K_1(\to K\pi\pi)\gamma$: the method by Gronau et al.

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Up-Down asymmetry

$$\mathcal{A} = \frac{\int_0^{\pi/2} d|\mathcal{M}|^2 d\theta - \int_{\pi/2}^{\pi} d|\mathcal{M}|^2 d\theta}{\int_0^{\pi} d|\mathcal{M}|^2 d\theta}$$

$$= \underbrace{\frac{\langle Im(\hat{n}\cdot(\vec{J}\times\vec{J}^*))\rangle}{\langle|\vec{J}|^2\rangle}}\cdot\underbrace{\frac{|C'_{7\gamma}|^2 - |C_{7\gamma}|^2}{|C'_{7\gamma}|^2 + |C_{7\gamma}|^2}}$$

$\vec{J}$: Helicity amplitude of $K_1 \to K\pi\pi$

λ : Polarization parameter

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

Polarization measurement using $B \to K_1(\to K\pi\pi)\gamma$: the method by Gronau et al.

Gronau, Grossman, Pirjol, Ryd hep-ph/0107254

Up-Down asymmetry

$$\mathcal{A} = \frac{\int_0^{\pi/2} d|\mathcal{M}|^2 d\theta - \int_{\pi/2}^{\pi} d|\mathcal{M}|^2 d\theta}{\int_0^{\pi} d|\mathcal{M}|^2 d\theta}$$

$$= \underbrace{\frac{\langle Im(\hat{n}\cdot(\vec{J}\times\vec{J}^*))\rangle}{\langle|\vec{J}|^2\rangle}}_{} \cdot \underbrace{\frac{|C'_{7\gamma}|^2 - |C_{7\gamma}|^2}{|C'_{7\gamma}|^2 + |C_{7\gamma}|^2}}_{}$$

$\vec{J}$: Helicity amplitude of $K_1 \to K\pi\pi$

λ : Polarization parameter

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

Source of imaginary part ⇨ **Breit-Wigner of two resonances**

$$K_1^+(p) \to \pi^+(p_1)\pi^-(p_2)K^+(p_3)$$

K^{*0} ($\pi^-(p_2) K^+(p_3)$), ρ^0 ($\pi^+(p_1)\pi^-(p_2)$)

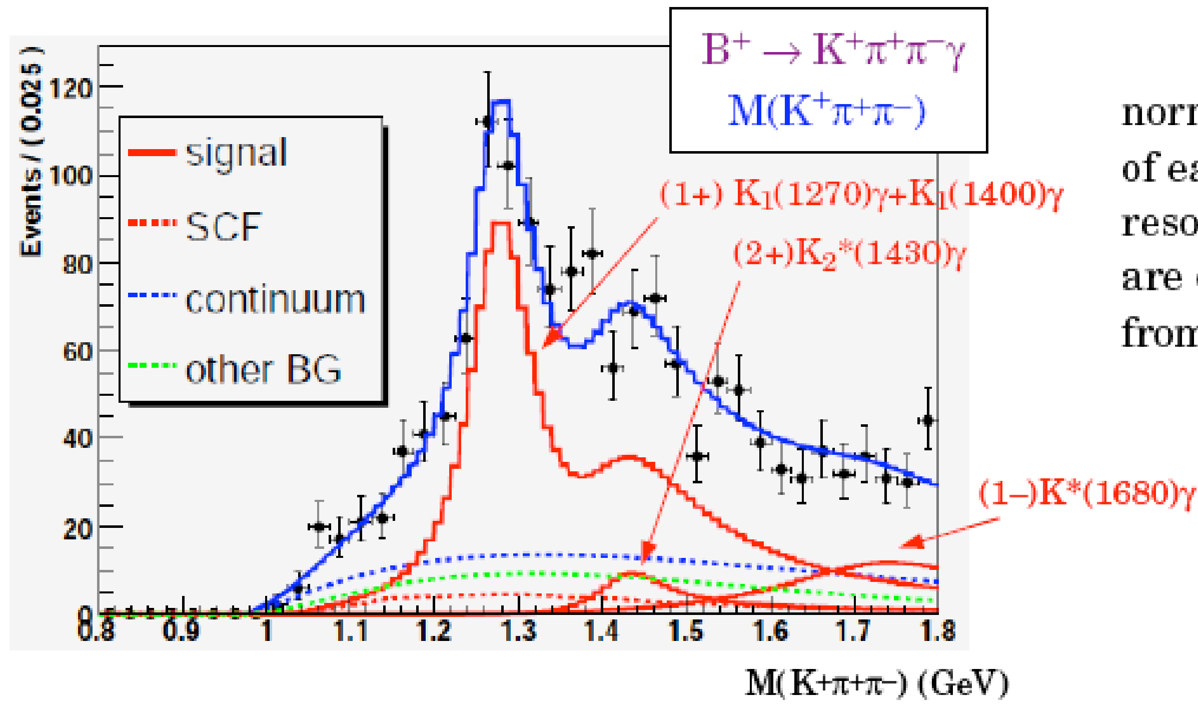
Belle Observation of B→$K_1(1270)\gamma$!

Branching ratio measurements: (x10^{-5})

Belle '02 '04

Babar '05

	B^+
$K_1(1270)\gamma$	4.3 ± 1.2
$K_1(1400)\gamma$	< 1.5
$K^*\pi^0\gamma$	2.0 ± 0.7
$K\rho^0\gamma$	< 2.0
$K^+\pi^+\pi^-\gamma$	2.76 ± 0.18
$K^0\pi^+\pi^-\gamma$	NA
$K^0\pi^+\pi^0\gamma$	4.5 ± 0.52
$K^+\pi^+\pi^0\gamma$	NA
$K^*\gamma$	4.57 ± 0.19
$K_2^*(1430)\gamma$	1.45 ± 0.43



Talk by S.Nishida at CKM2008

Belle reported an observation of B→$K_{1(1270)}\gamma$ (7.3σ).
So far, B→$K_{1(1400)}\gamma$ has not yet been observed.

DDLR method: improved polarization measurement using $B \to K_1(\to K\pi\pi)\gamma$

EK, Le Yaouanc, A.Tayduganov, PRD83 ('11)

$$\frac{d\Gamma}{ds_{13}ds_{23}d\cos\theta} \propto \frac{1}{4}|\vec{J}|^2(1+\cos^2\theta) + \lambda\frac{1}{2}Im\left[\vec{n}\cdot(\vec{J}\times\vec{J}^*)\right]\cos\theta$$

DDLR method **Applied to the τ polarization measurement at ALEPH** ***Davier, Duflot, Le Diberder, Rouge, PLB306 '93***

✓ The polarization information is not only in the angular distribution but also in the Dalitz distribution.

✓ When the PDF depends only linearly to the polarization parameter, one can simplify the analysis using the ω variable.

$$\omega(s_{13}, s_{23}, \cos\theta) \equiv \frac{2Im[\vec{n}\cdot(\vec{J}\times\vec{J}^*)]\cos\theta}{|\vec{J}|^2(1+\cos^2\theta)}$$

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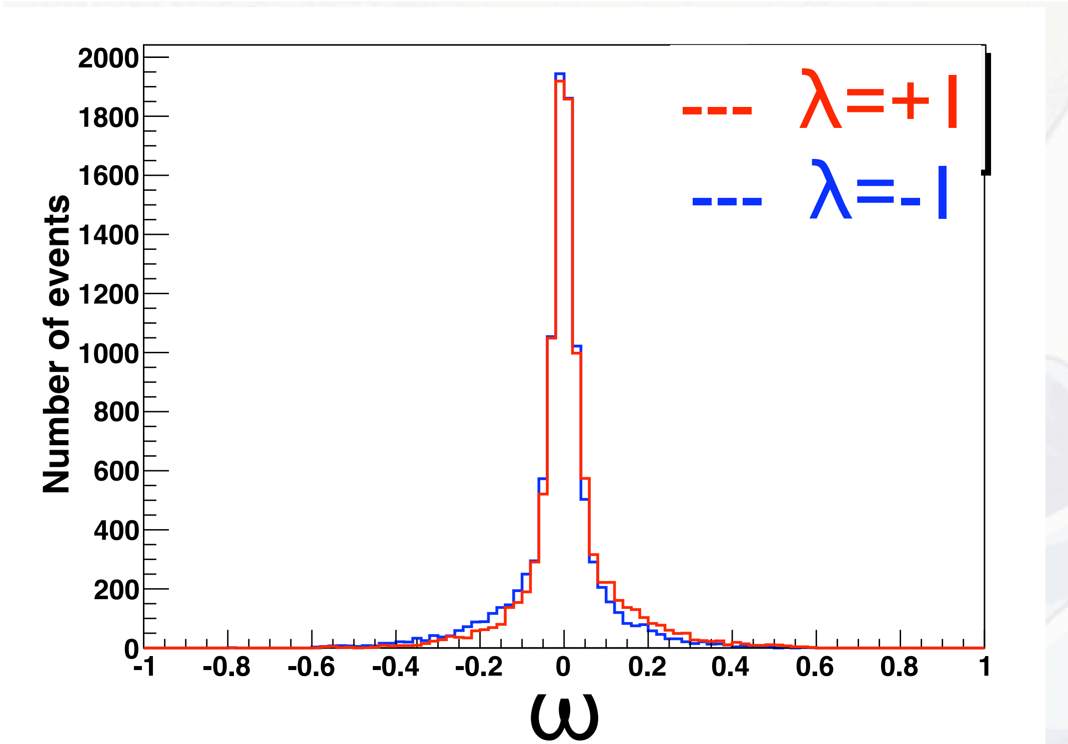
$$\omega(s_{13}, s_{23}, \cos\theta) \equiv \frac{2Im[\vec{n}\cdot(\vec{J}\times\vec{J}^*)]\cos\theta}{|\vec{J}|^2(1+\cos^2\theta)}$$

How to use the ω variable?

For each event $\xi_i(s_{13}, s_{23}, \cos_\theta)$:

1. Compute the ω value knowing the function J $(s_{13}, s_{23}, \cos_\theta)$.
2. Make a ω distribution.
3. Polarization is then obtained!

$$\lambda = \frac{\langle\omega\rangle}{\langle\omega^2\rangle}$$



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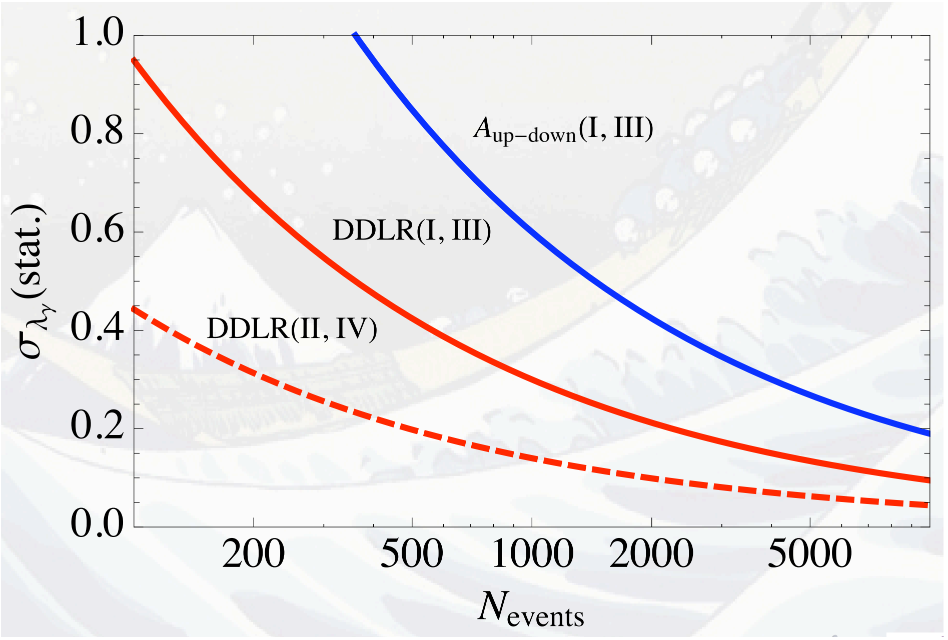
Stat. errors to $\lambda_\gamma^{(SM)}$ from $B \to K_1(1270)\gamma$

N_{events}	10^3	10^4
(I) $B^+ \to K^+\pi^-\pi^+\gamma$	±0.18	±0.06
(II) $B^+ \to K^0\pi^+\pi^0\gamma$	±0.12	±0.04
(III) $B^0 \to K^0\pi^+\pi^-\gamma$	±0.18	±0.06
(IV) $B^0 \to K^+\pi^-\pi^0\gamma$	±0.12	±0.04

~10% accuracy achievable!



Our study shows that DDLR method reduces the statistical errors in λ by a factor of two comparing to the up-down asymmetry.

DDLR method: improved polarization measurement using $B \to K_1(\to K\pi\pi)\gamma$

EK, Le Yaouanc, A. Tayduganov, PRD83 ('11)

$$\omega(s_{13}, s_{23}, \cos\theta) \equiv \frac{2Im[\vec{n}\cdot(\vec{J}\times\vec{J}^*)]\cos\theta}{\cdots}$$

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

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

N_{events}

Our study shows that DDLR method reduces the statistical errors in λ by a factor of two comparing to the up-down asymmetry.

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

A. Tayduganov, EK, Le Yaouanc, to be published in PRD

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

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

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

2. Model dependent extraction i.e. theoretical estimate

Modeling J function:

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 $K_1 \to K\pi\pi$

A. Tayduganov, EK, Le Yaouanc, to be published in PRD

Model parameters are extracted by fitting to data:

✓ $Br(K_{1(1270)} \to K^*\pi)/Br(K_{1(1270)} \to \rho K) = 0.24 \pm 0.09$

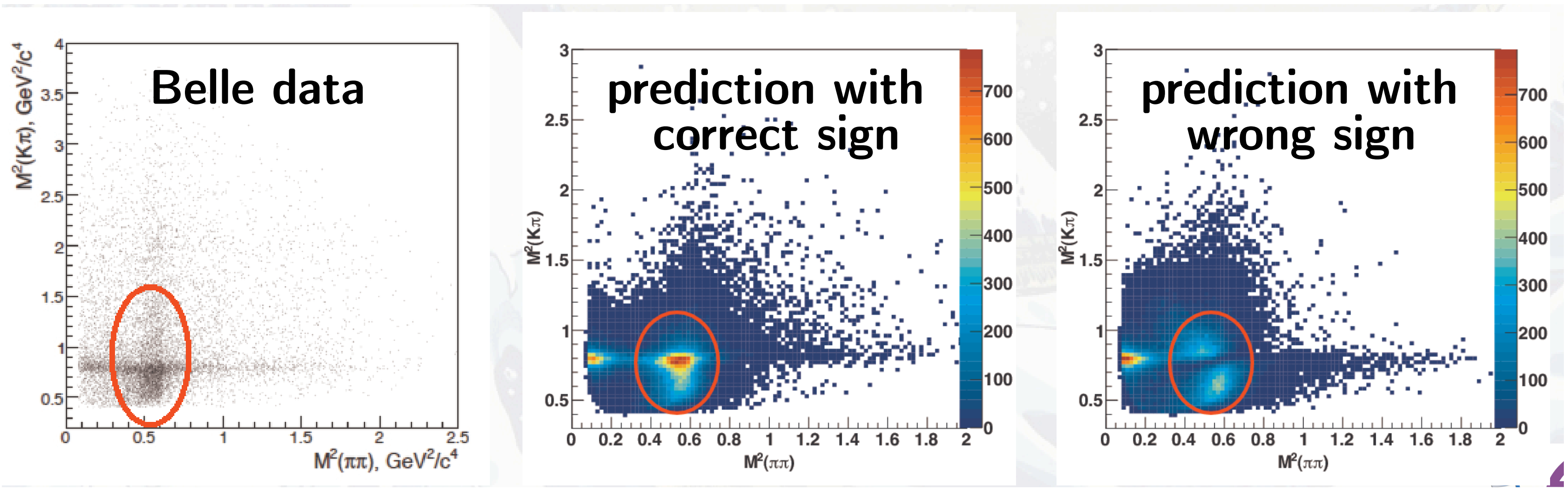
✓ $Br(K_{1(1400)} \to \rho K)/Br(K_{1(1400)} \to K^*\pi) = 0.01 \pm 0.01$

✓ $Br(K_{1(1400)} \to K^*\pi)_{D\text{-wave}}/Br(K_{1(1400)} \to K^*\pi)_{S\text{-wave}} = 0.04 \pm 0.01$

✓ $Br(K_{1(1270)} \to K^*\pi)_{D\text{-wave}}/Br(K_{1(1270)} \to K^*\pi)_{S\text{-wave}} = 2.67 \pm 0.95$

Brandenburg et al, Phys Rev Lett, 36 ('76)
Otter et al, Nucl Phys, B106 ('77)
Daum et al, Nucl Phys, B187 ('81)

Recent Belle measurement of $B \to J/\Psi K_1$ fixed the relative phase!!



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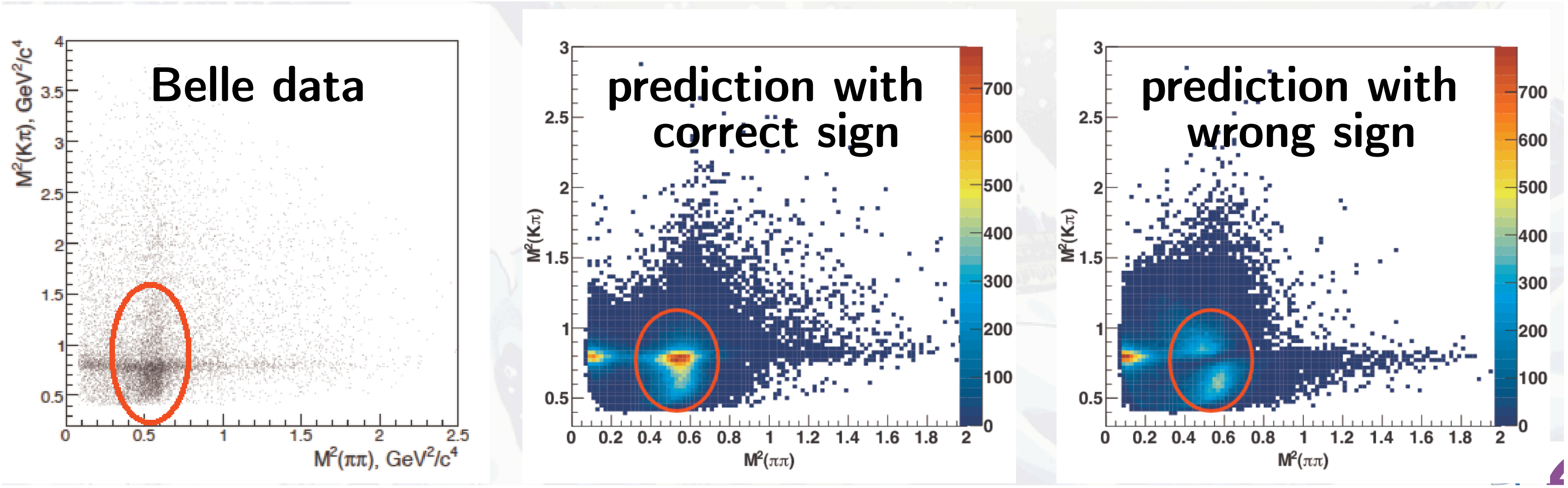

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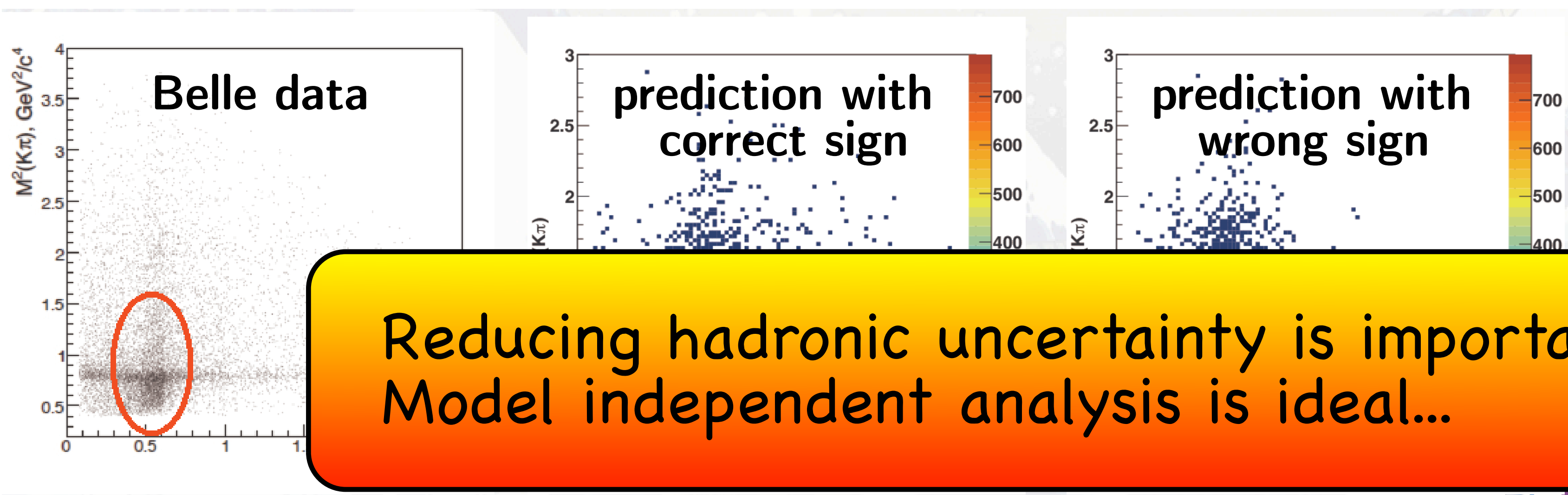

Reducing hadronic uncertainty is important.
Model independent analysis is ideal...