Searching for New Physics by studying the photon polarization in $b \to s\gamma$

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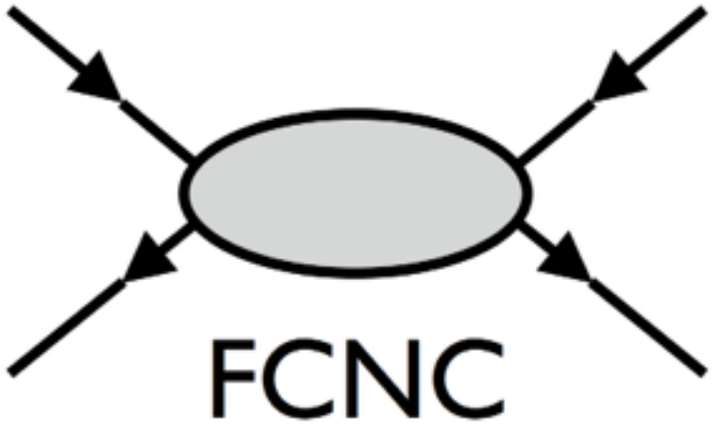
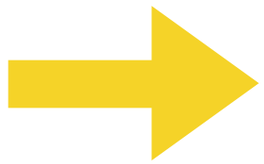
In collaboration with Emi Kou (LAL) , Cai-Dian Lu (IHEP)

9th TeV workshop 2014.05.17 @ Zhongshan University

Flavour Physics beyond SM

- Powerful **indirect search of new physics** through quantum loop effect





mass scale of NP

δ_i/M^2

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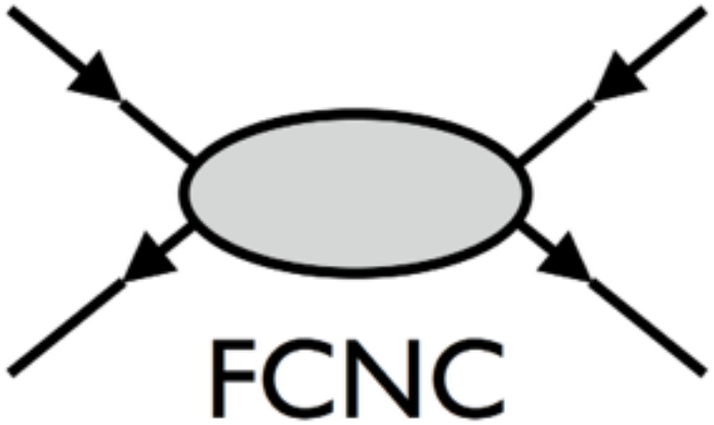

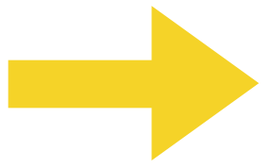

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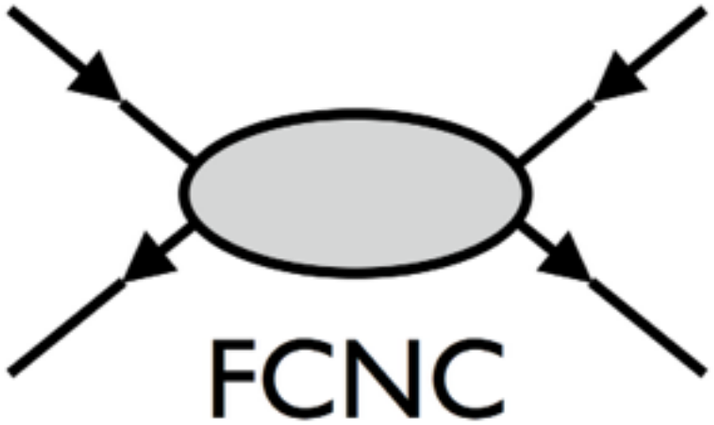

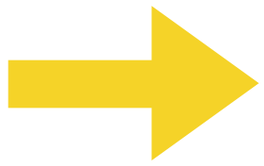

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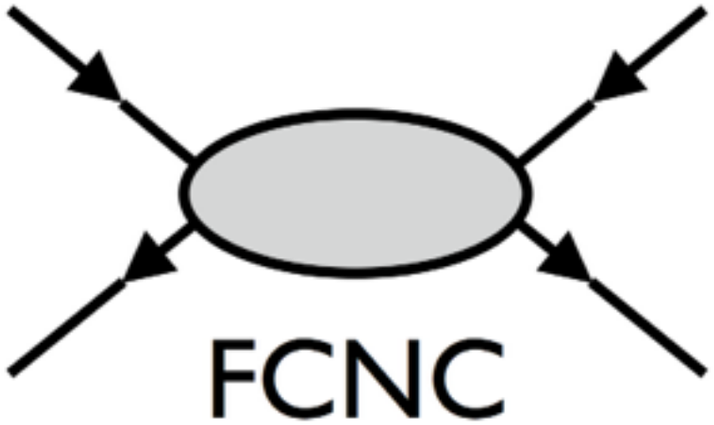

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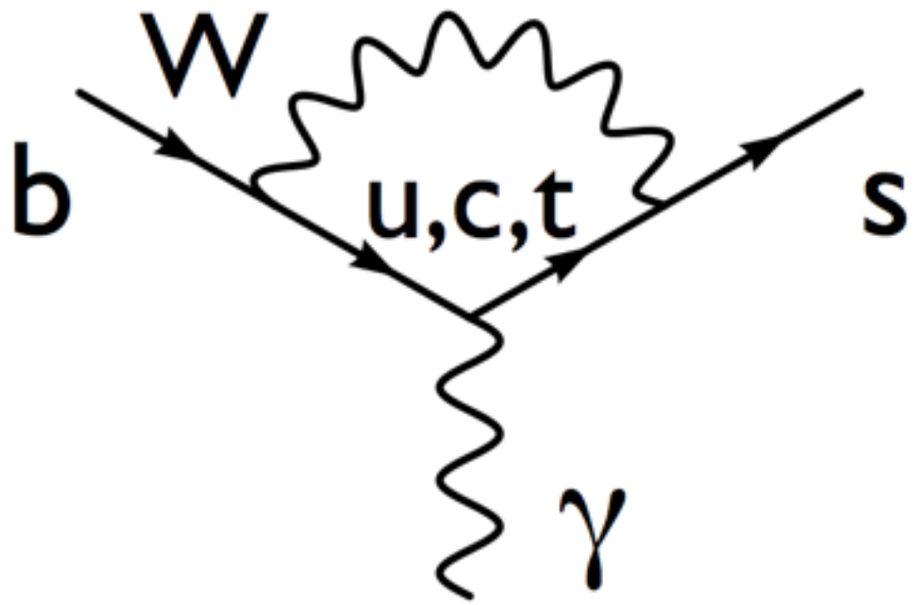
Photon Polarization in $b \to s\gamma$

Photon Polarization in b→sγ

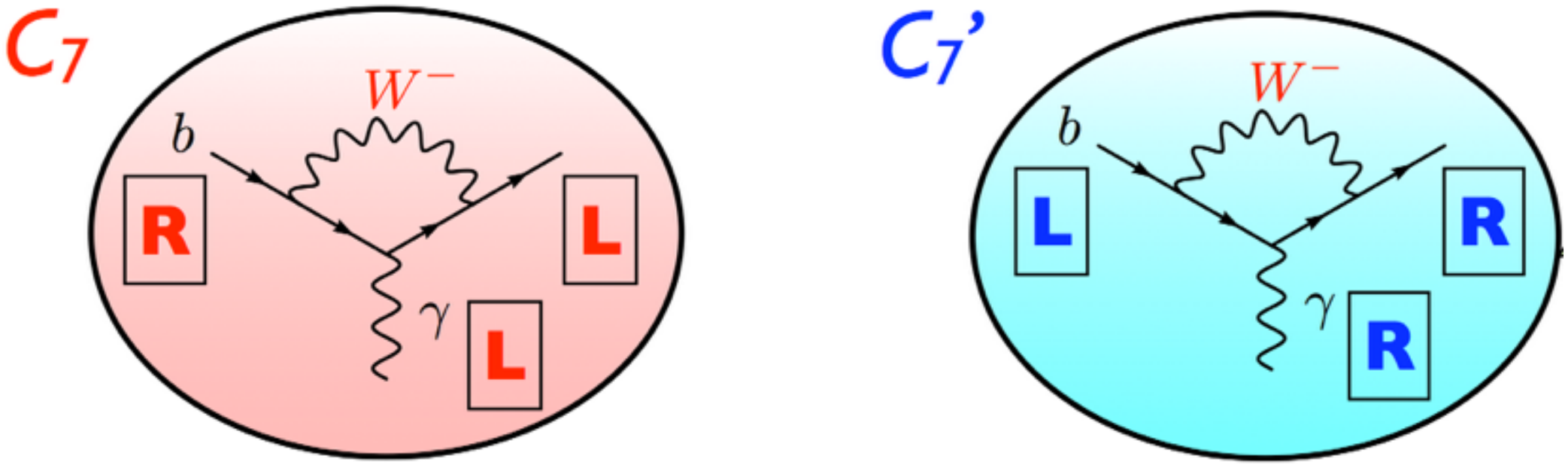
- b→sγ is a good probe of SM and NP



Photon Polarization in b→sγ

- b→sγ is a good probe of SM and NP
- b→sγ process has particular Dirac structure

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



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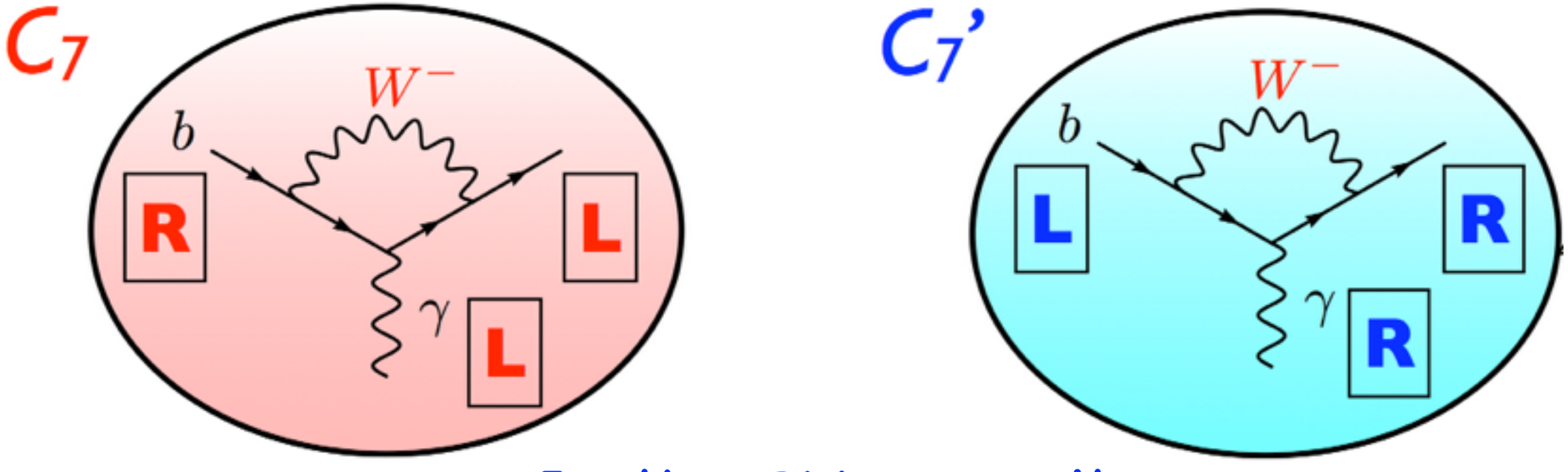

In the SM, opposite chirality is suppressed by m_s/m_b

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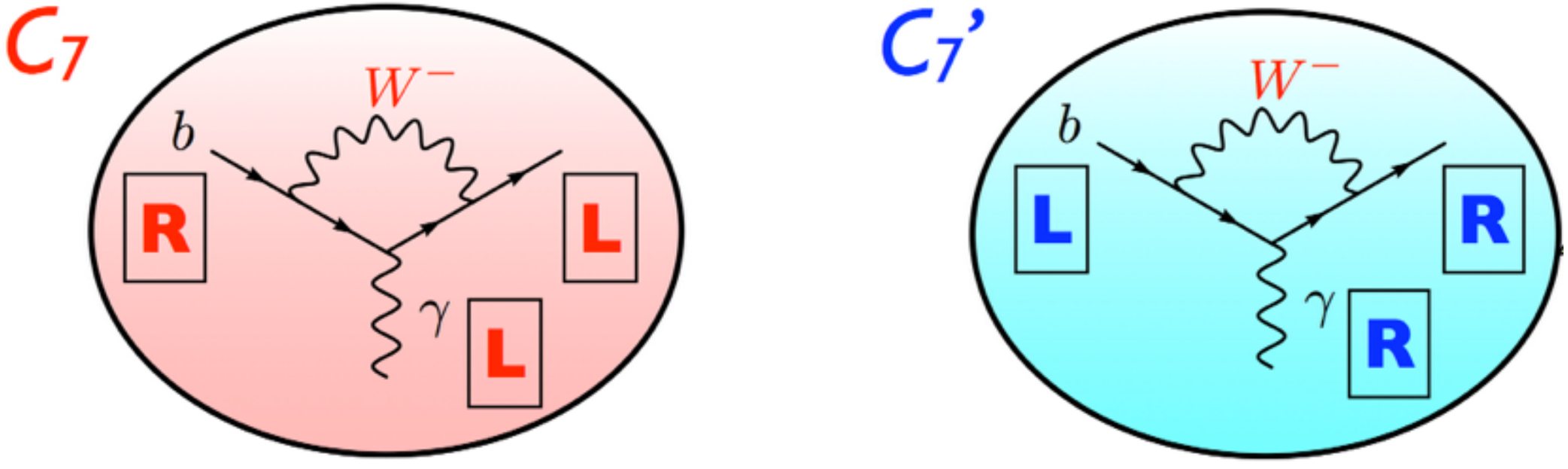

☞**Left-Handedness** in the SM, due to left-handed current

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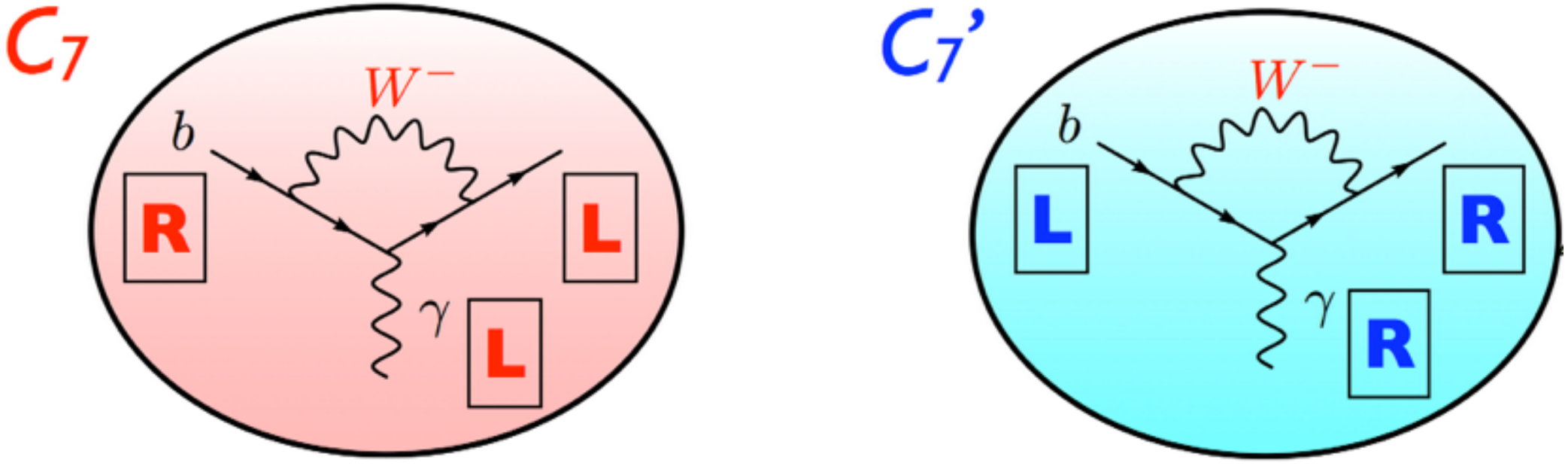


☞**Left-Handedness** in the SM, due to left-handed current

☞**Possible large NP effect** due to "chiral enhancement"

Example: Left-Right Symmetric Model

[E.Kou, C.-D.Lu, F.-S.Yu, JHEP2013]

- Gauge symmetry broken in two steps

$$SU(2)_L \times SU(2)_R \times U(1)_{B-L} \to SU(2)_L \times U(1)_Y \to U(1)_{\rm EM}$$

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

by $\langle \Delta_R \rangle = \begin{pmatrix} 0 & 0 \\ v_R & 0 \end{pmatrix}$ $\langle \Phi \rangle = \begin{pmatrix} \kappa & 0 \\ 0 & \kappa' e^{i\omega} \end{pmatrix}$

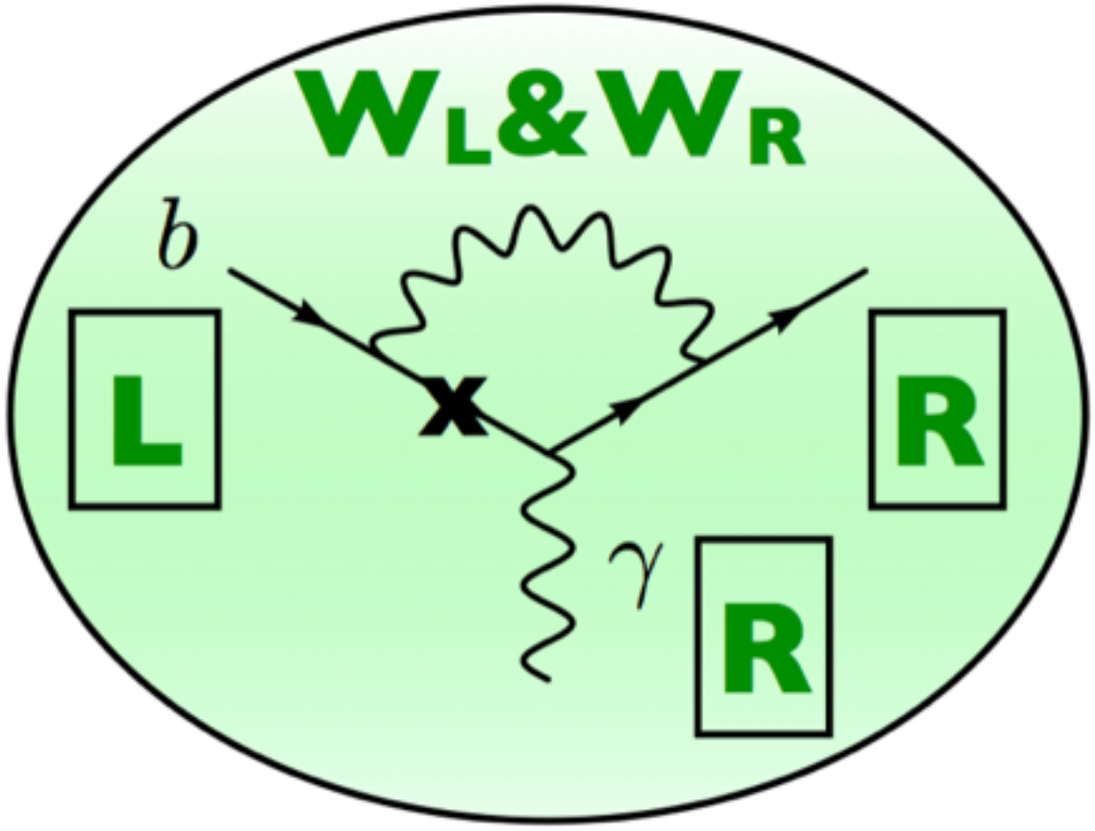
$\kappa, \kappa', v_L \ll v_R$ Right handed mass very large

- Gauge bosons: left- and right-handed currents

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

mass eigenstates are mixture of W_L & W_R

Dominant Contribution to Wrong Polarization in LRSM



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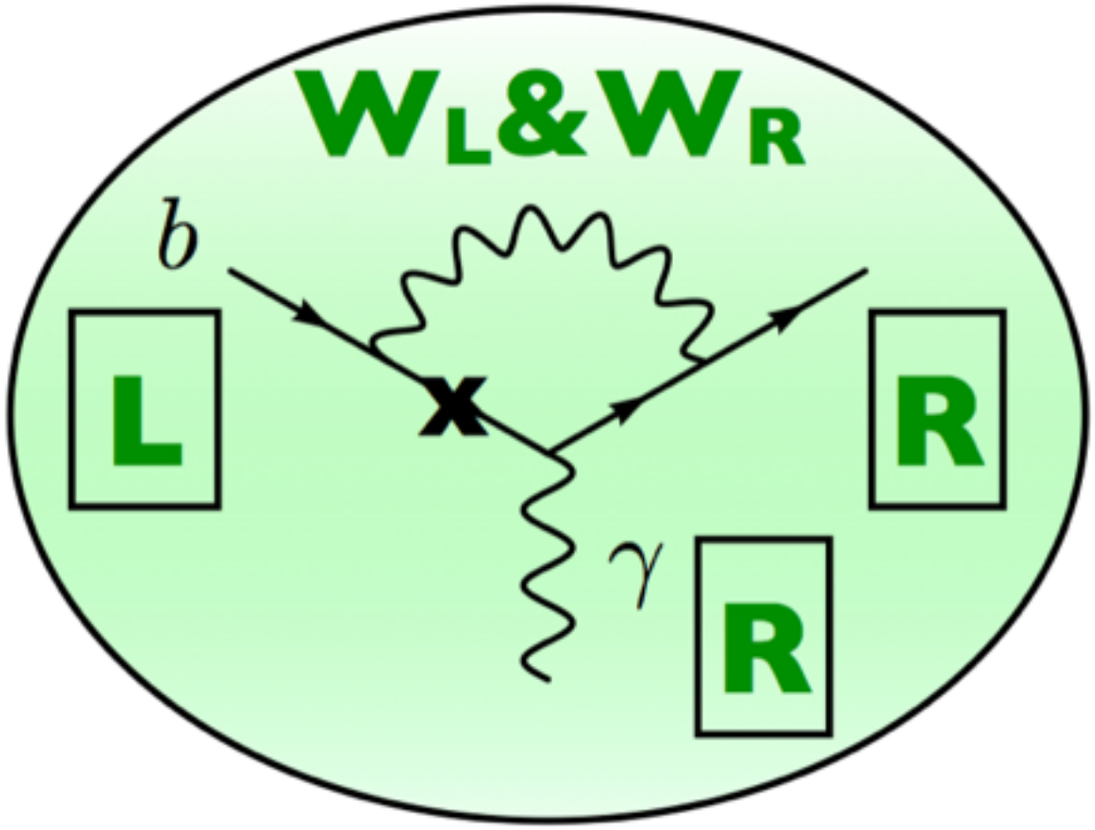

$$C'_{7\gamma}(\mu_{W_1})_{W_1} = \frac{1}{2}\frac{m_t}{m_b}\frac{g_R^2}{g_L^2}\frac{V_{ts}^{R*}}{V_{ts}^{L*}}\frac{M_{W_1}^2}{M_{W_2}^2}\sin 2\beta e^{-i\omega} A_{\mathrm{LR}}(x_t)$$

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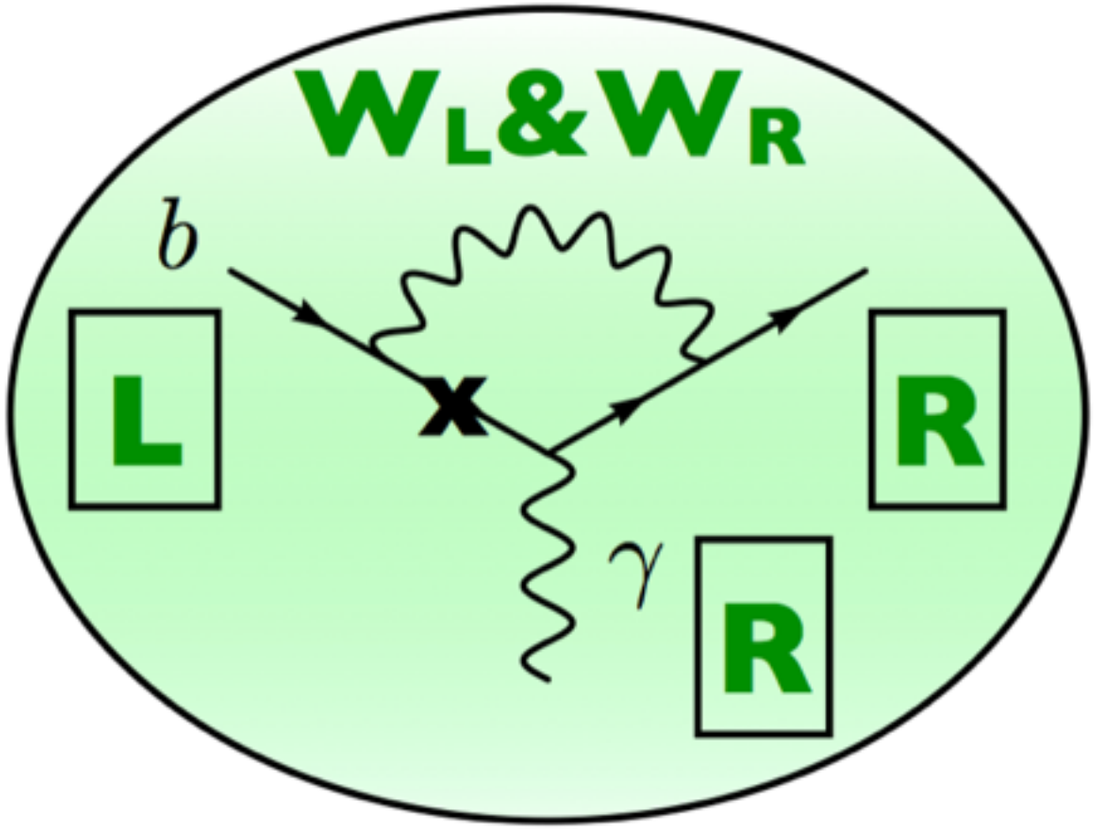

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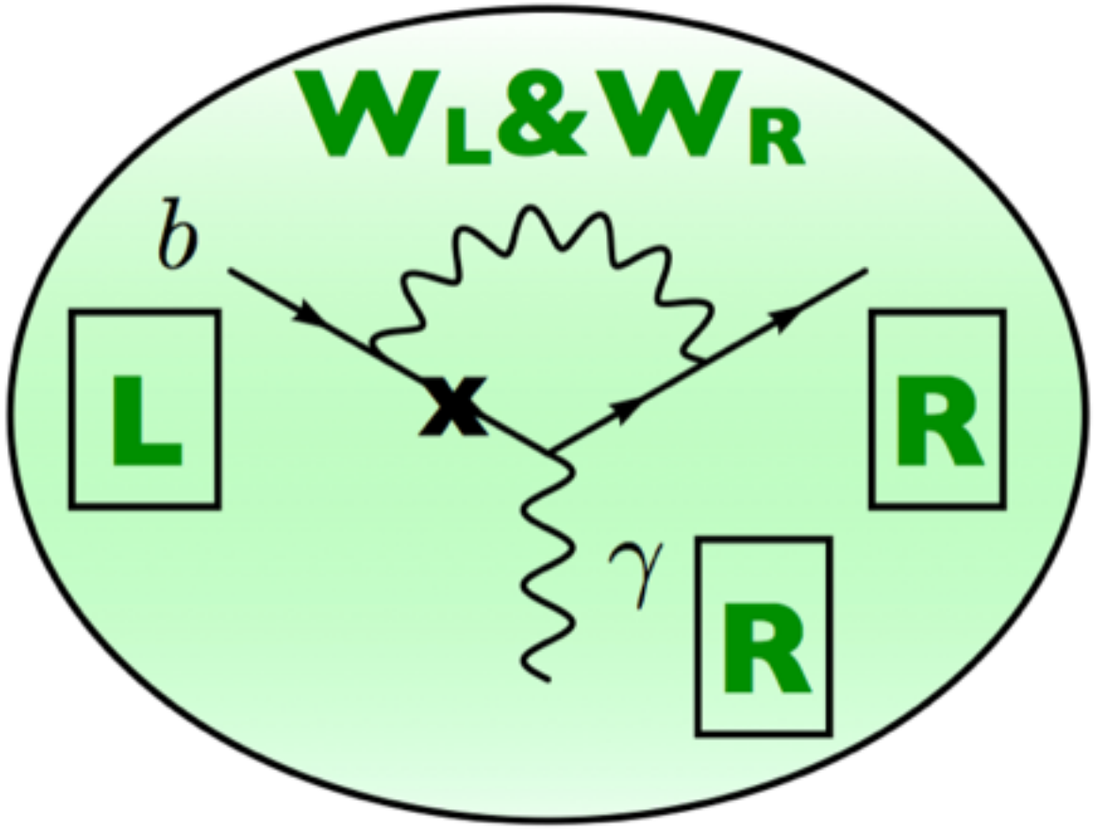

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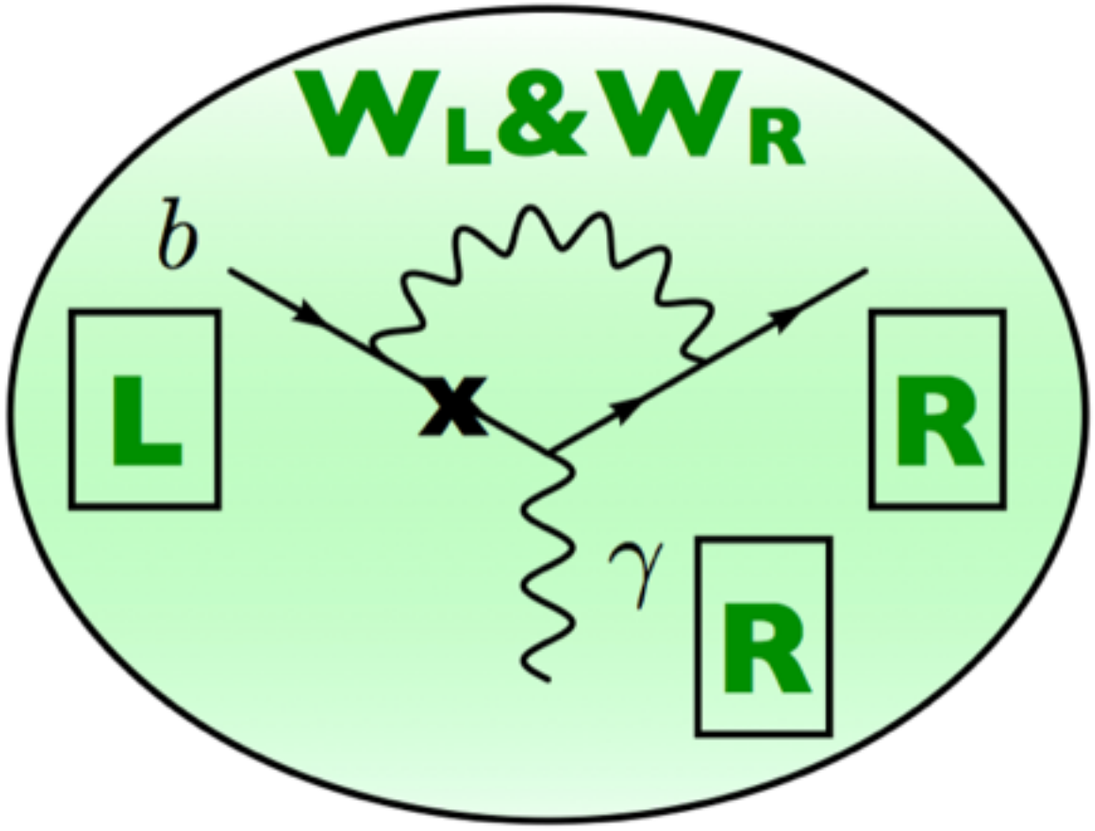

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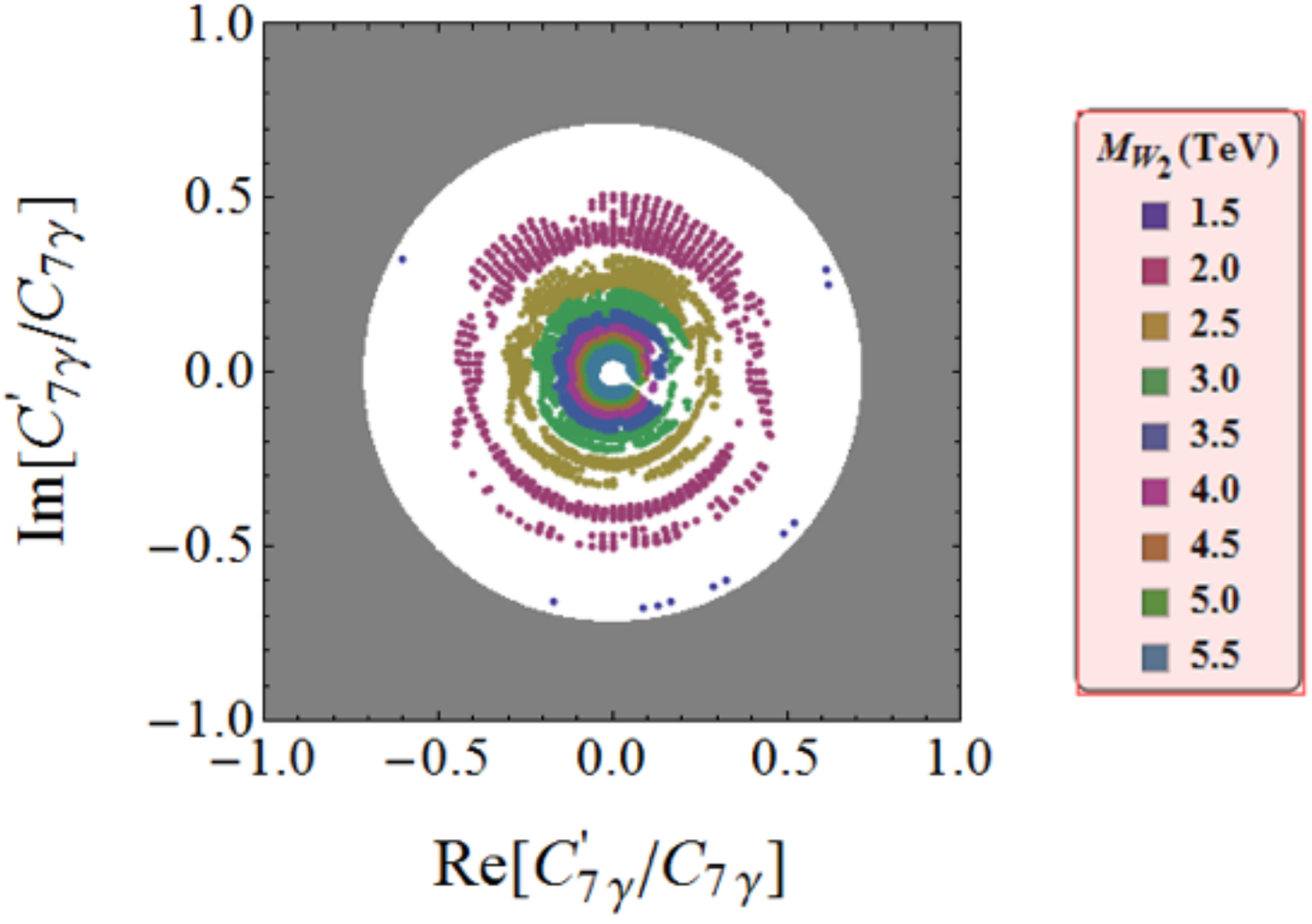
Chiral enhancement term

Photon Polarization in the LRSM

[E.Kou, C.-D.Lu, F.-S.Yu, JHEP2013]

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

M_H=20TeV



How to Measure Polarization

- Angular analysis in e+e- low mass region in

$$\bar{B} \to K^* e^+ e^-$$

[Kruger, Matias, PRD71]
[Becirevic, Schneider, NPB854]

- Time-dependent CP asymmetry in

$$B \to f_{CP}\gamma \quad (K^0_S \pi^0 \gamma)$$

[Atwood et.al. 1997']

- Measurement of hadronic state helicity in

$$\bar{B} \to A\gamma \to P_1 P_2 P_3 \gamma$$

[Gronau et.al. PRL88]
[Kou et.al. PRD83]

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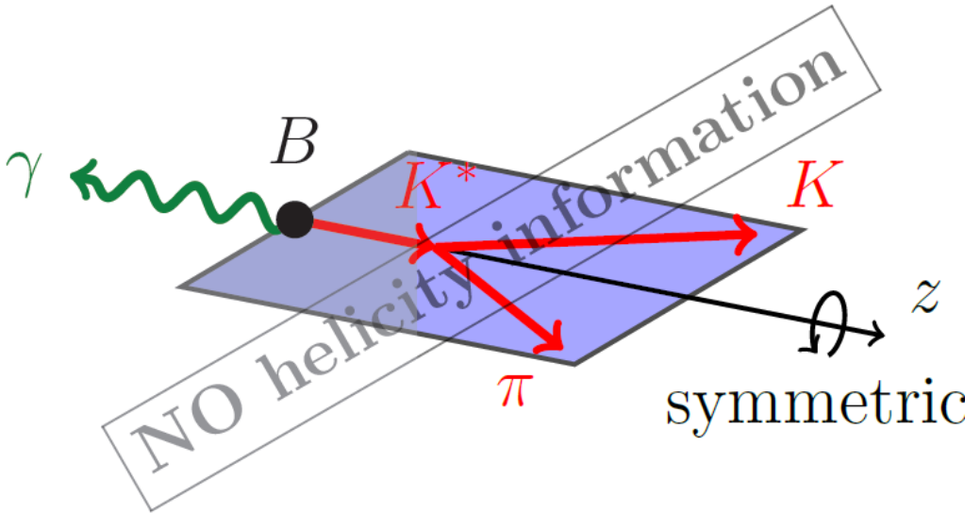

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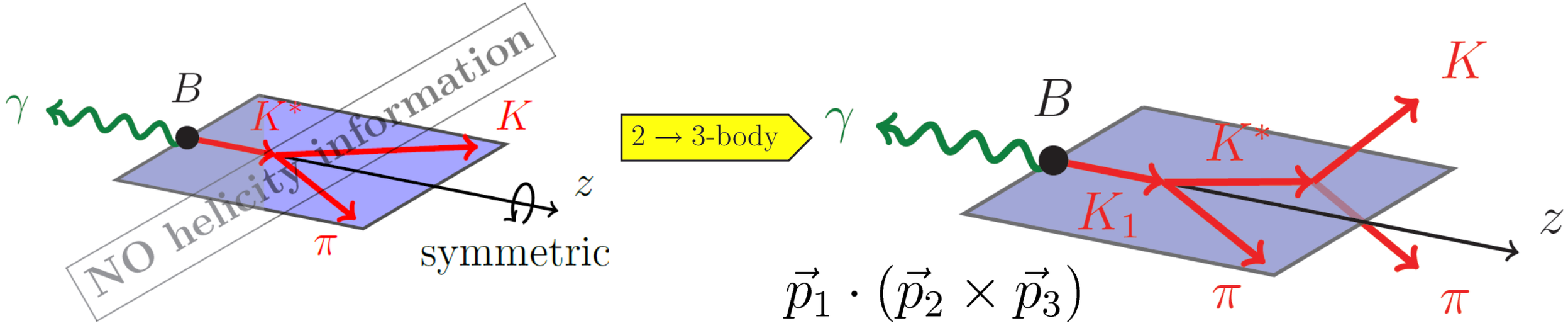

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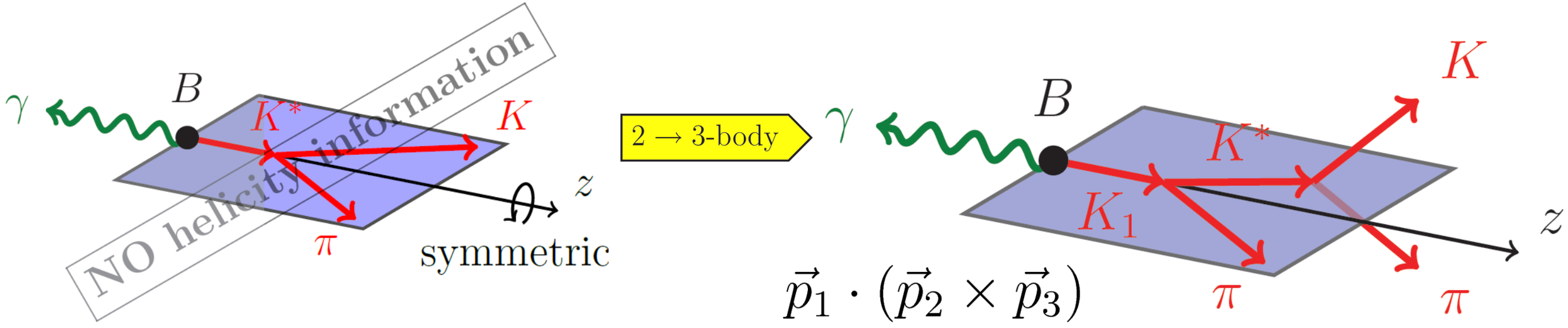
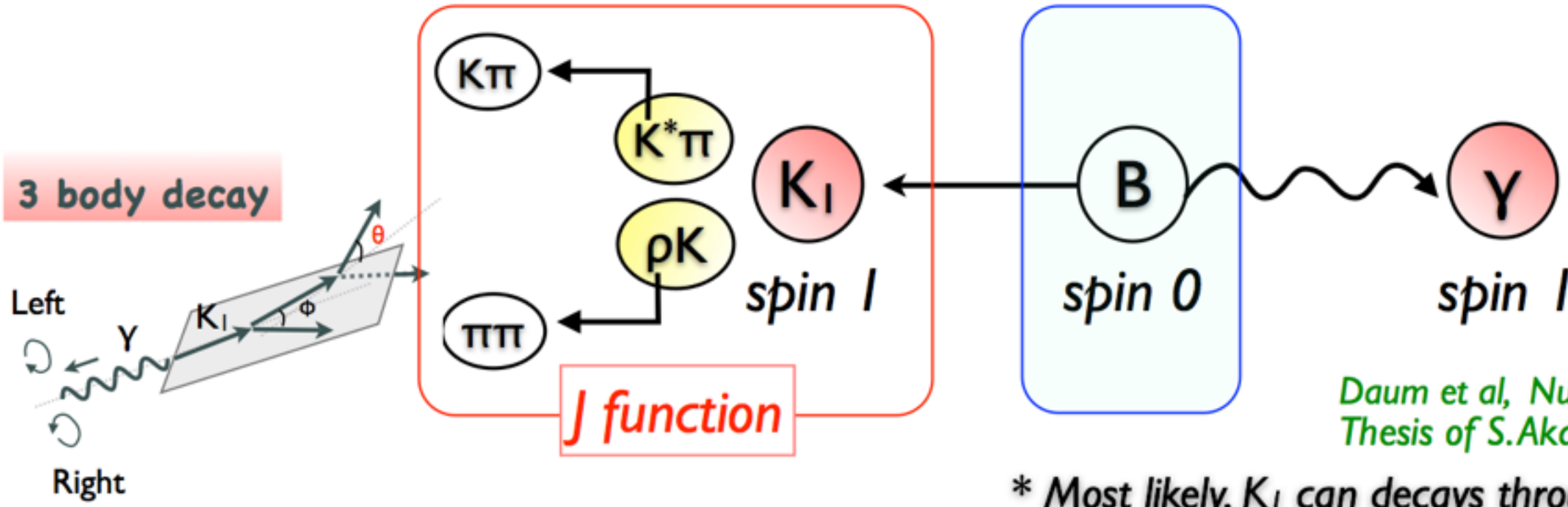


$\bar{B} \to K_1\gamma \to K\pi\pi\gamma$ **has been studied**

[Gronau, et al, 2002'; Kou, et al, 2011']

$$\lambda_\gamma \equiv \frac{\left|\mathcal{M}(\overline{B} \to \overline{K}_{1R}\gamma_R)\right|^2 - \left|\mathcal{M}(\overline{B} \to \overline{K}_{1L}\gamma_L)\right|^2}{\left|\mathcal{M}(\overline{B} \to \overline{K}_1\gamma)\right|^2} \approx \frac{\left|C'_{7\gamma}/C_{7\gamma}\right|^2 - 1}{\left|C'_{7\gamma}/C_{7\gamma}\right|^2 + 1}$$

Polarization determination with $B \to K_1(\to K\pi\pi)\gamma$



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

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

The up-down asymmetry

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

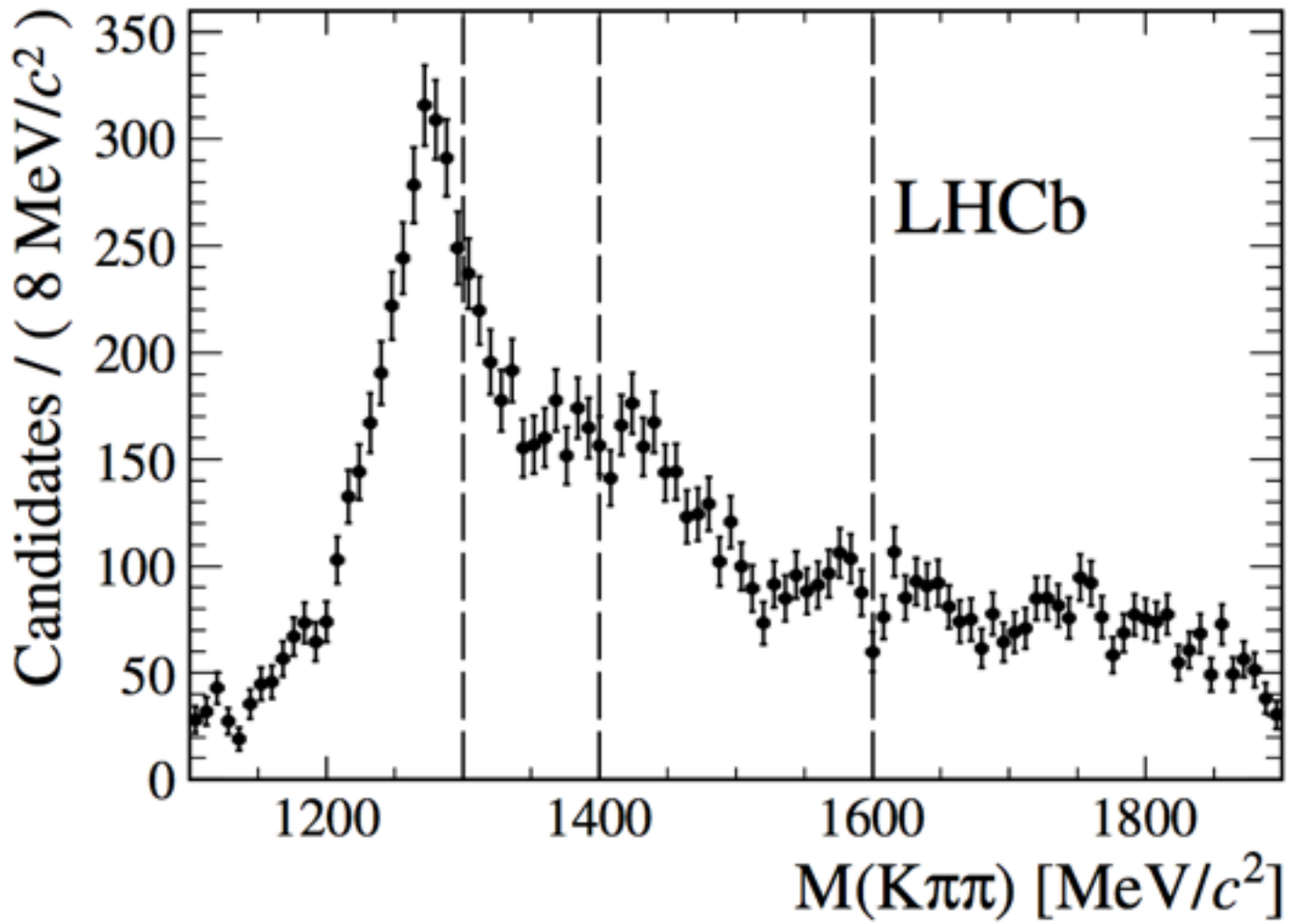
$$\mathcal{A}_{ud} = \frac{\int_0^1 \cos\theta \frac{d\Gamma}{d\cos\theta} - \int_{-1}^0 \cos\theta \frac{d\Gamma}{d\cos\theta}}{\int_{-1}^1 \cos\theta \frac{d\Gamma}{d\cos\theta}} = \frac{3}{4} \frac{\langle Im(\hat{n}\cdot(\vec{J}\times\vec{J}^*))\rangle}{\langle|\vec{J}|^2\rangle} \frac{|c_R|^2 - |c_L|^2}{|c_R|^2 + |c_L|^2}$$

Photon Polarization

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

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

$B^{\pm} \to K^{\pm}\pi^{\mp}\pi^{\pm}\gamma$ measured by LHCb

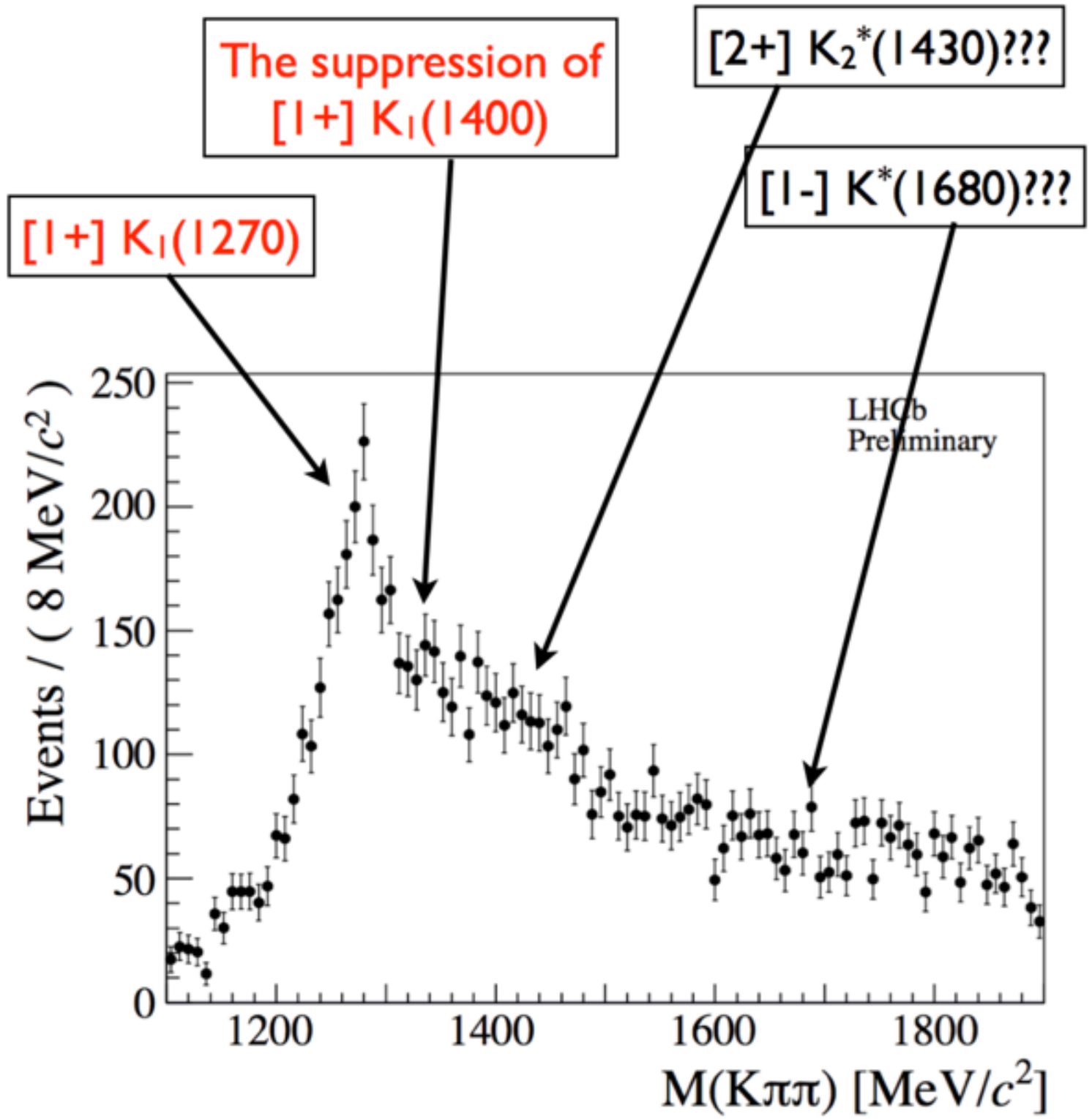


[LHCb, PRL2014']

	[1.1, 1.3]	[1.3, 1.4]	[1.4, 1.6]	[1.6, 1.9]
$\mathcal{A}_{\rm ud}$	6.9 ± 1.7	4.9 ± 2.0	5.6 ± 1.8	-4.5 ± 1.9

The up-down asymmetry, proportional to photon polarization, is different from zero at 5.2σ significant level

Detailed information of K resonances are required



Conclusion

- Photon polarization is useful to search for NP
- Wrong polarization may be large in LRSM, to be tested in the future experiments
- To determine the photon polarization, we need to study the details of hadronic K resonances decays

Thank you!