Photon polarization measurement by B->Kππγ

Emi Kou
(LAL-IN2P3)

Novel aspects of b to s transitions: investigating new channels
CPT Marseille, 5-7 October 2015

Outline

★ B2TiP: Belle II physics working group

★ The $b \to s\gamma$ as a window to BSM

★ Belle II prospect and comparison to LHCb

★ Theoretical uncertainties

★ Conclusions

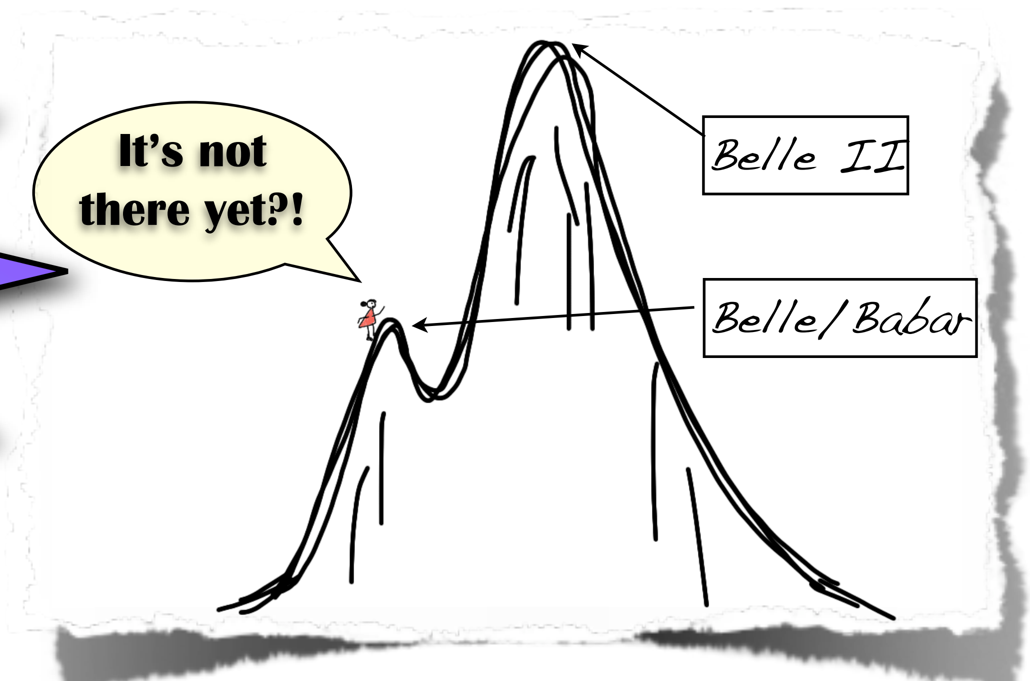
Discovery in Flavour Physics

Well motivated. But we need to improve the sensitivity?

- New physics models predict naturally deviation from SM in flavour and CP violating phenomena.
- But then, what is the indication of the non-appearance of new physics? And where/how to search it now?

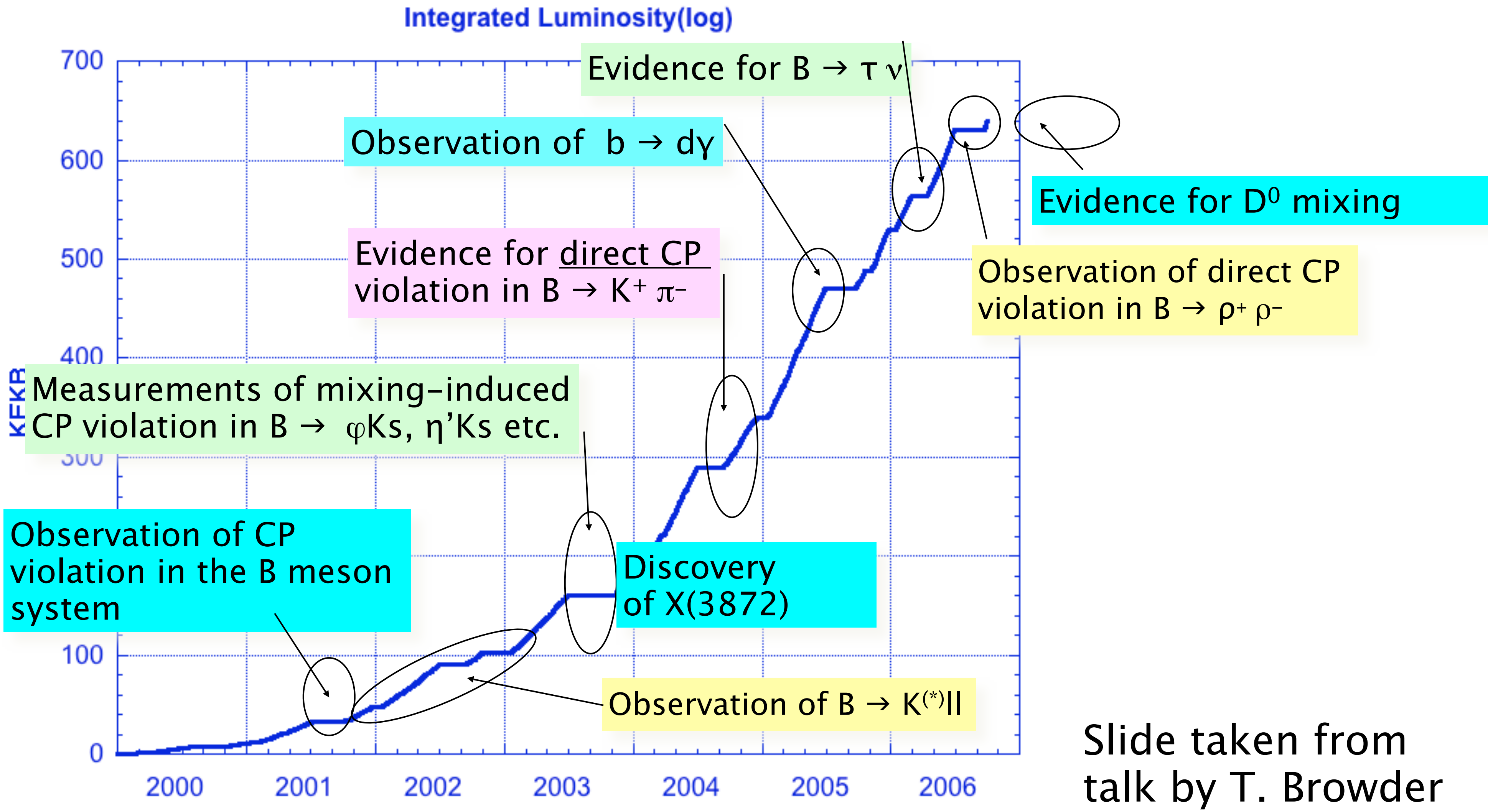
Increase the sensitivity to new physics by an order of magnitude!

SuperKEKB/Belle II



Legacy of Babar/Belle

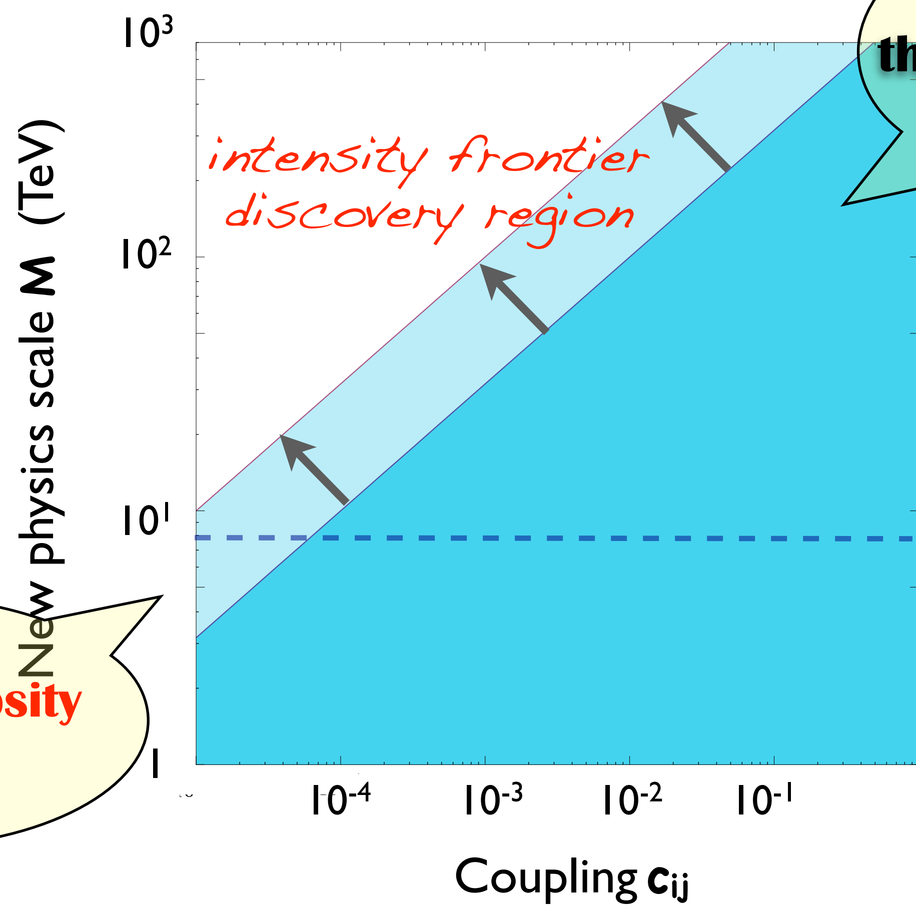
Many 2-3σ seen, disappeared, unclear etc...



Slide taken from talk by T. Browder

Discovery through precision

$$\Delta_{NP} = (\text{exp.} - \text{SM}) \pm \sqrt{(\sigma_{exp})^2 + (\sigma_{SM})^2}$$
$$= c/(M_{NP})^{n=2}$$



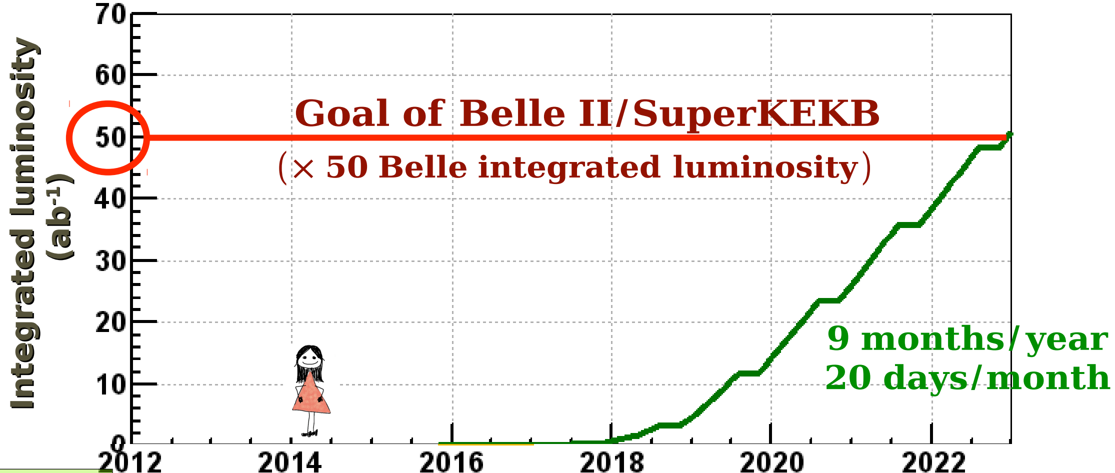
How do we push this bound by an order of magnitude???

High Luminosity machine!

SuperKEKB

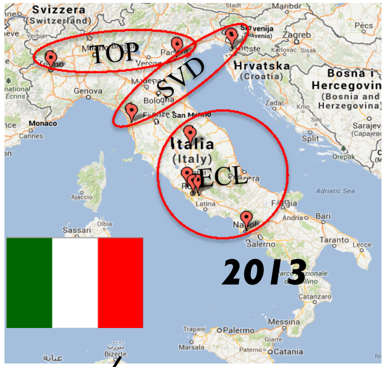
Channels which shows 2-3σ deviation ---> reduce error by a factor of "a few"!
Channels which is consistent to SM within 2-3σ errors ---> NP possible if we reduce error by a factor of ?

Belle II Collaboration

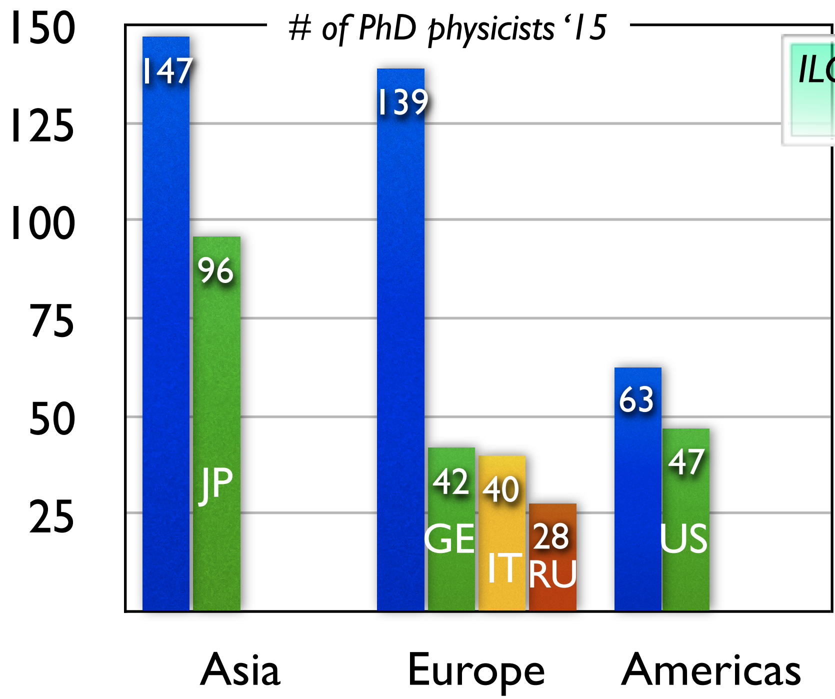


Belle II	1 ab^{-1} →	start! →	10 ab^{-1} →	50 ab^{-1}
LHCb	3fb^{-1} →	run II →	8fb^{-1} →	23fb^{-1}

In 2013, many of the former Babar/SuperB-Italy joined.

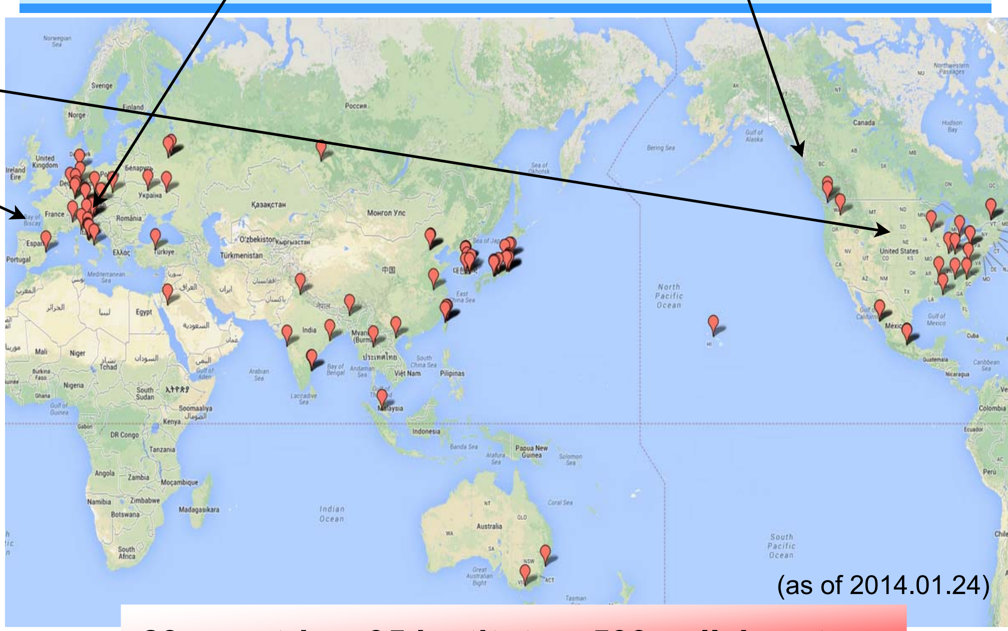


(keeping Babar/ATLAS membership)



ILC community in Belle II

Belle II Collaboration



Statistics is not all about Belle II!

$$\Delta_{NP} = (\text{exp.} - \text{SM}) \pm \sqrt{(\sigma_{exp})^2 + (\sigma_{SM})^2}$$

The strength of Belle II (by me)!!

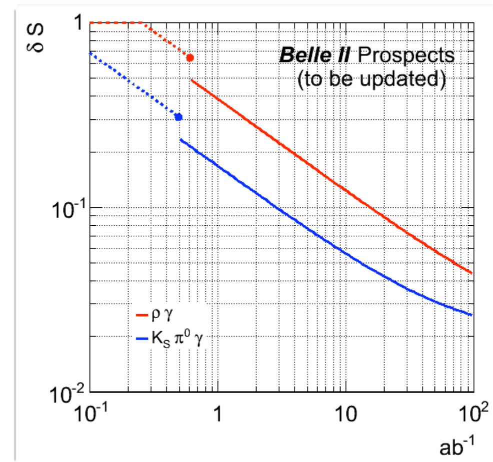
Statistics:

Remove also "reducible systematic errors"

$$\sigma_{Belle\ II} = \sqrt{(\sigma_{stat}^2 + \sigma_{syst}^2)\frac{\mathcal{L}_{Belle}}{50\text{ab}^{-1}} + \sigma_{ired}^2}$$

Particle ID:

Jump in the δS sensitivity!



Challenges for legendary channels?!

Time dependent CPV in $\pi^0\pi^0$??

- photon conversion makes vertexing possible → time-dependent analysis

$S_{CP}^{\pi^0\pi^0}$: important **new** input for isospin analysis

⇒ Belle2 opens new possibilities

Missing energy channels!

Full reconstruction of B

- modes w/ multiple ν's
- Improved low p_T tracking - more slow π in tag side D* candidates

Why B2TiP?

Why B2TiP

E.K & P. Urquijo

http://kds.kek.jp/getFile.py/access?contribId=14&sessionId=0&resId=0&materialId=slides&confId=15226

KEK where Belle II is hosted is the natural gathering point where flavour physics experts meet to discuss and develop topics of flavour physics for Belle II.

What's new in Belle II compared to Babar/Belle?

- ➡ Efficiencies and precision of the new hardware
- ➡ New analysis softwares and methods

What's new in theory after Babar/Belle & LHCb result?

- ➡ Progresses in QCD
- ➡ New physics models and their constraints
- ➡ New observables

NEW IDEAS

Deliverable: "KEK green report" by the early 2017

9 working groups

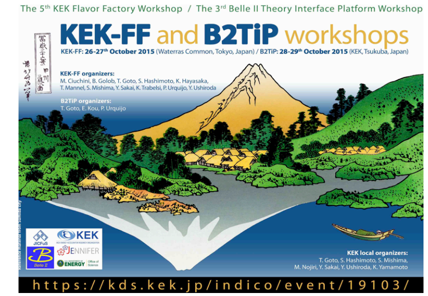
Find details on the B2TiP website

https://belle2.cc.kek.jp/~twiki/bin/view/Public/B2TIP

WG1	G. De Nardo, A. Zupanic, M. Tanaka, F. Tackmann, A. Kronfeld
WG2	A. Ishikawa, J. Yamaoka, U. Haisch, T. Feldmann
WG3	T. Higuchi, L. Li Gioi, J. Zupan, S. Mishima
WG4	J. Libby, Y. Grossman, M. Blanke
WG5	P. Goldenzweig, M. Beneke, C.-W. Chiang, S. Sharpe
WG6	G. Casarosa, A. Schwartz, A. Kagan, A. Petrov
WG7	Ch.Hanhart, R.Mizuk, R.Mussa, C.Shen, Y.Kiyo, A.Polosa, S.Prelovsek
WG8	K. Hayasaka, T. Feber, E. Passemar, J. Hisano
WGNP	R.Itoh, F.Bernlochner, Y.Sato, U.Nierste, L.Silvestrini, J.Kamenik, V.Lubicz

I: Leptonic/Semi-leptonic II: Radiative/Electroweak III: phi1(beta)/phi2(alpha) IV: phi3 (gamma)
V: Charmless/hadronic B decays VI: Charm VII: Quarkonium(like) VIII: Tau & low multiplicity NP: New Physics

Workshop schedule



To receive information, subscribe to the mailing list b2tip@... send an e-mail to Ph.Urquijo

- *02/14* *Approval of B2TiP*
- 06/14 Kickoff meeting
- *10/14* *WS-KEK KEKFF*
- *02/15* *NP-WG KIT workshop*
- ~04/15 WS (nonKEK) Krakow
- *~10/15* *WS-KEK KEKFF (Tokyo)*
- *~05/16* *WS (nonKEK) Pittsburgh*
- *~11/16* *B2TiP Report Camp @ MIAPP (Munich)*
- *early 17* *Editorial meeting*

REPORT PLANNING

Phase 1(2014)

- Identifying the 'Golden channels'

Phase II (2015)

- Detailed studies (theory uncertainties, experimental simulations)
- New ideas???

Phase III (2016)

- Finalizing the analysis/text
- Editing

Krakow workshop (~100 participants)

Golden channels to be worked out!

Group	Observables	Mode	SM or CKM Fit Expectation	Belle 2014	Babar 2014	Belle II 5 /ab	Belle II 50/ ab	LHCb 2014	LHCb 8/fb	LHCb 50/fb
ϕ_1/ϕ_2 WG page	$\sin(2\phi_1)$	$B \to J/\psi K_S$		$0.667 \pm 0.023 \pm 0.012(1.4^\circ)$		0.7°	0.4°		1.6°	0.6°
	S	$B \to \phi K_S^0$		$0.90^{+0.09}_{-0.19}$		0.053	0.018		0.2	0.04
		$B \to \eta' K_S^0$		$0.68 \pm 0.07 \pm 0.03$		0.028	0.011			
		$B \to K_S^0 K_S^0 K_S^0$		$0.30 \pm 0.32 \pm 0.08$		0.100	0.033			
	ϕ_2	$B \to \pi\pi$, $B \to \rho\pi$, $B \to \rho\rho$		$(85 \pm 4)^\circ$ (Belle + Babar)		2°	1°			
ϕ_3 WG page	ϕ_3	$B \to D^{(*)}K/\pi$ (total)		$(68 \pm 14)^\circ$		6°	1.5°			
	ϕ_3	$B \to D^{(*)}K/\pi$ (CP eigenstate)								
	ϕ_3	$B \to D^{(*)}K/\pi$ (CB/DCS decays)								
	ϕ_3	$B \to D^{(*)}K/\pi$ (Self-conjugate)								
	ϕ_3	$B \to D^{(*)}K/\pi$ (SCS decays)								
Hadronic B WG page	A	$B \to K_S^0\pi^0$		$-0.05 \pm 0.1 \pm 0.05$		0.07	0.04			
		$B \to K^*\pi$								
		$B \to K\rho$								
		$B \to K^*\phi$								
		$B \to K^*\rho$								
		$B \to K_S K^+ K^-$								
		$B \to K^+ K^- \pi^0$								
		$B \to K^+ \pi^0 \pi^0$								
		$B \to K_S \pi^+ \pi^0$								
Semileptonic & Leptonic WG page	$V_{cb}[10^{-3}]$ inclusive	$B \to X_c \ell\nu$		$41.6(1 \pm 0.024_{fit})$		1.2%				
	$V_{cb}[10^{-3}]$ exclusive	$B \to D^* \ell\nu$		$37.5(1 \pm 0.030_{exp} \pm 0.027_{thy})$		1.8%	1.4%			
	$V_{ub}[10^{-3}]$ exclusive	$B \to \pi\ell\nu$ (Hadronic tag)		$3.52(1 \pm 0.095_{fit})$		4.4%	2.3%			
	$\mathcal{B}[10^{-6}]$	$B \to \tau\nu$ (Hadronic tag)		$96(1 \pm 0.26)$		10%	5%			
	$\mathcal{B}[10^{-6}]$	$B \to \mu\nu$				20%	7%			
	$\mathcal{R}$	$B \to D\tau\nu$ (Hadronic tag)			$0.440(1 \pm 0.165)$	5.6%	3.4%			
	$\mathcal{R}$	$B \to D^*\tau\nu$ (Hadronic tag)			$0.332(1 \pm 0.090)$	4.4%	2.3%			
Radiative & Electroweak WG page	A_{CP}	$B \to X_{s+d}\gamma$		$2.2 \pm 4.4 \pm 0.8$ %		1.0%	0.5%			
	ΔA_{CP}	$B \to X_s\gamma$		not measured yet	$+5.0 \pm 3.9 \pm 1.5$ %	1.7%	0.7%			
	$\mathcal{B}[10^{-6}]$	$B \to X_d\gamma$		not measured yet	$9.2(1 \pm 0.22 \pm 0.25)$	x.x%	x.x%			
	$\mathcal{S}$	$B \to K_S^0\pi^0\gamma$		$-0.10 \pm 0.31 \pm 0.07$		0.11	0.035			
	$\mathcal{S}$	$B \to \rho\gamma$		$-0.83 \pm 0.65 \pm 0.18$		0.23	0.07			
	$\mathcal{B}[10^{-6}]$	$B \to K\nu\bar{\nu}$		< 40						
	$\mathcal{B}[10^{-6}]$	$B \to K^*\nu\bar{\nu}$		< 55						
	$\mathcal{R}_{X_s}$	$B \to X_s\ell^+\ell^-$		20%		7%	2.0%			
Charm WG page	$\mathcal{B}[10^{-3}]$	$D_s \to \mu\nu$		$5.31(1 \pm 0.053 \pm 0.038)$		2.9%	0.9%			
	$\mathcal{B}[10^{-3}]$	$D_s \to \tau\nu$		$5.70(1 \pm 0.037 \pm 0.054)$		3.5%	2.3%			
	$\mathcal{B}[10^{-6}]$	$D^0 \to \gamma\gamma$		< 1.5		30%	25%			
	$A_{CP}[10^{-4}]$	$D^0 \to K^+K^-$		$-32 \pm 21 \pm 9$		11	6			
	$A_{CP}[10^{-2}]$	$D^0 \to \pi^0\pi^0$		$0.03 \pm 0.64 \pm 0.10$		0.29	0.09			
	$A_{CP}[10^{-2}]$	$D^0 \to K_S^0\pi^0$		$-0.21 \pm 0.16 \pm 0.09$		0.08	0.03			
	A_Γ			$-0.03 \pm 0.21 \pm 0.08$		0.1	0.03			
	$x[10^{-2}]$	$D^0 \to K_S^0\pi^+\pi^-$		$0.56 \pm 0.19^{+0.07}_{-0.13}$		0.14	0.11			
	$y[10^{-2}]$	$D^0 \to K_S^0\pi^+\pi^-$		$0.30 \pm 0.15^{0.05}_{0.08}$		0.08	0.05			
	$abs(q/p)$	$D^0 \to K_S^0\pi^+\pi^-$		$0.90^{+0.16}_{-0.15}{}^{+0.08}_{-0.06}$		0.10	0.07			
	ϕ	$D^0 \to K_S^0\pi^+\pi^-$		$-6 \pm 11^{+4}_{-5}$		6°	4°			
Tau WG page	$\mathcal{B}[10^{-9}]$	$\tau \to \mu\mu\mu$		< 21		< 3.0	< 0.3			
		$\tau \to K_S\pi^0\nu$								
		$\Upsilon(3S) \to$ missing energy								

-- Main.PhillipUrquijo - 2015-05-14

This topic: B2TiP > WebHome > B2TIPGoldenModes
Topic revision: r4 - 2015-08-25 - EmiKou

- **All the numbers to be filled** (with some document attached if necessary)
- We will prepare next i) Bs Golden channel table ii) Y(3/6 s) table iii) "Next-to-Golden" channel table.

https://belle2.cc.kek.jp/~twiki/bin/view/B2TiP/B2TIPGoldenModes

B2TiP Krakow 2015 highlights

https://d2comp.kek.jp/record/283

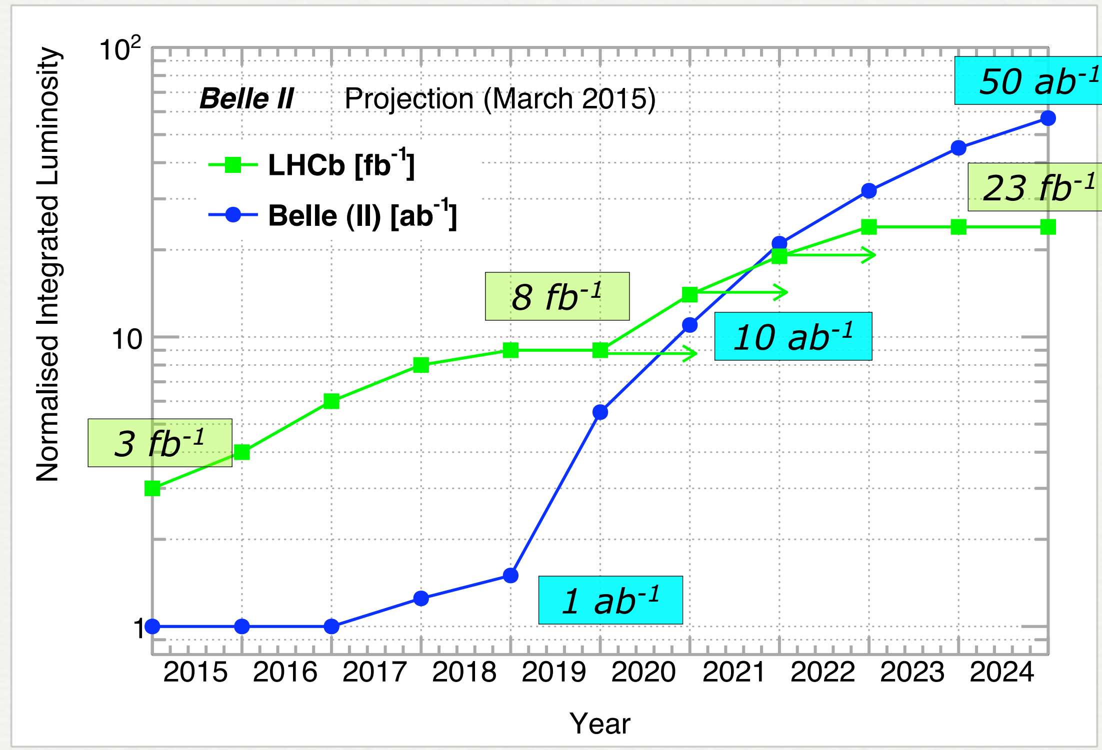
Summary of the 2nd B2TiP workshop (Krakow)*

In this short note, we summarize the report from the working groups on the last day of the 2nd B2TiP Workshop at Krakow (26-29 April, 2015).

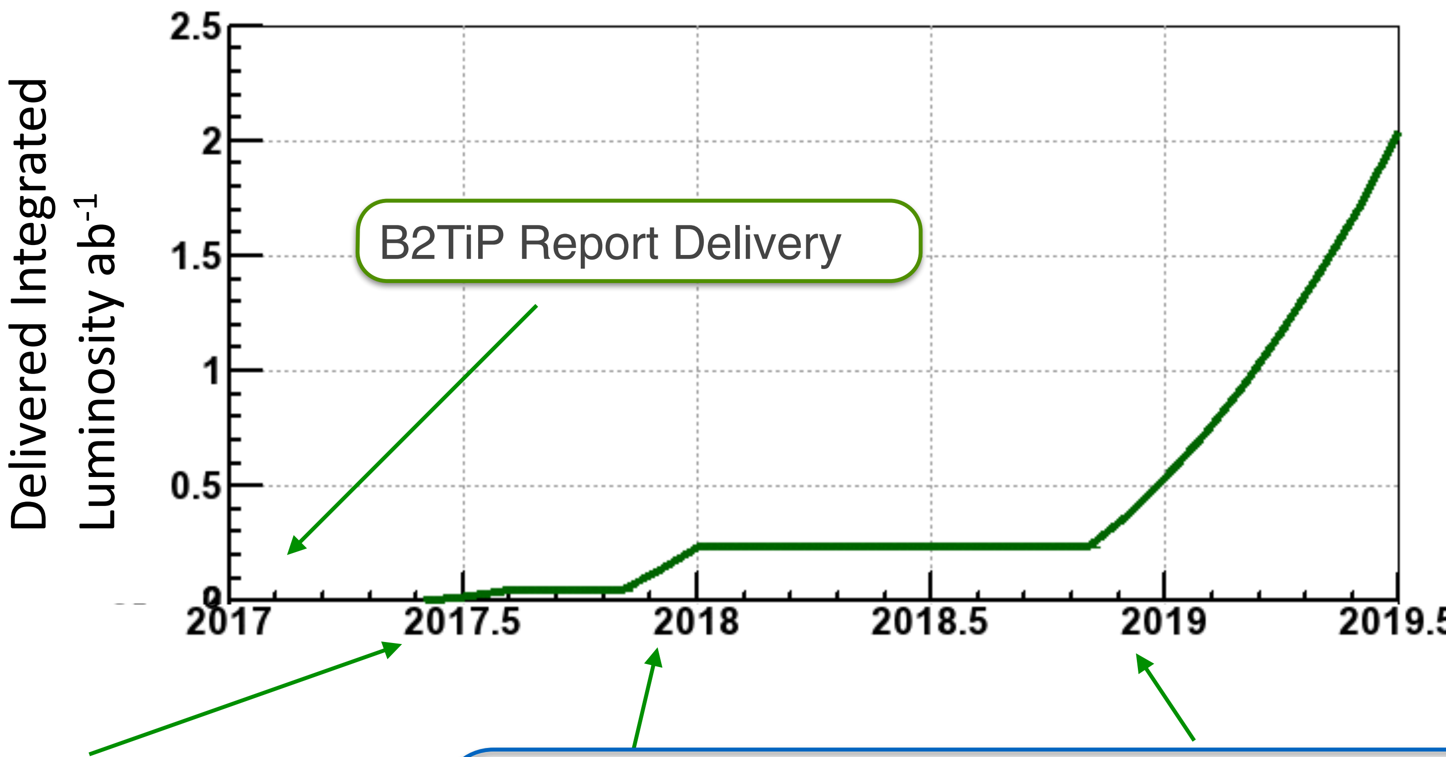
The working group conveners are asked to propose five top priority observables, i.e. *Belle II golden modes*, and scrutinize them within the B2TiP working groups, namely by estimating the precision of the theoretical uncertainties and the achievable precision at Belle II with 5, 10, and 50 ab^{-1} of data.

Many new Belle II simulation results presented!

Many LHCb talks: comparison or competition???



The first data samples: "first-physics"



Phase 1
First collisions.
BEAST commissioning detector
Belle II not rolled in
"Beam analysis"

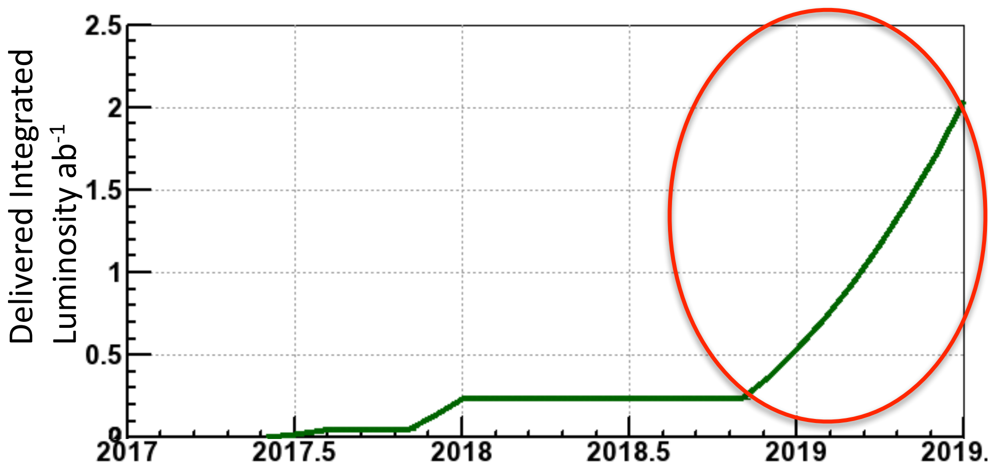
Phase 2
Belle II rolled in
SVD & PXD not installed
"Commissioning & unique data sets"

Phase 3
Full detector.
All systems go.

We need to maximise "first-physics" scientific/ publication output in phase 2 & early phase 3.

Phase 3 Physics: First O(1 ab^{-1})

Full detector operation. Considering options for balancing unique, non-Υ(4S) samples, and Υ(4S) samples. Proposals required.

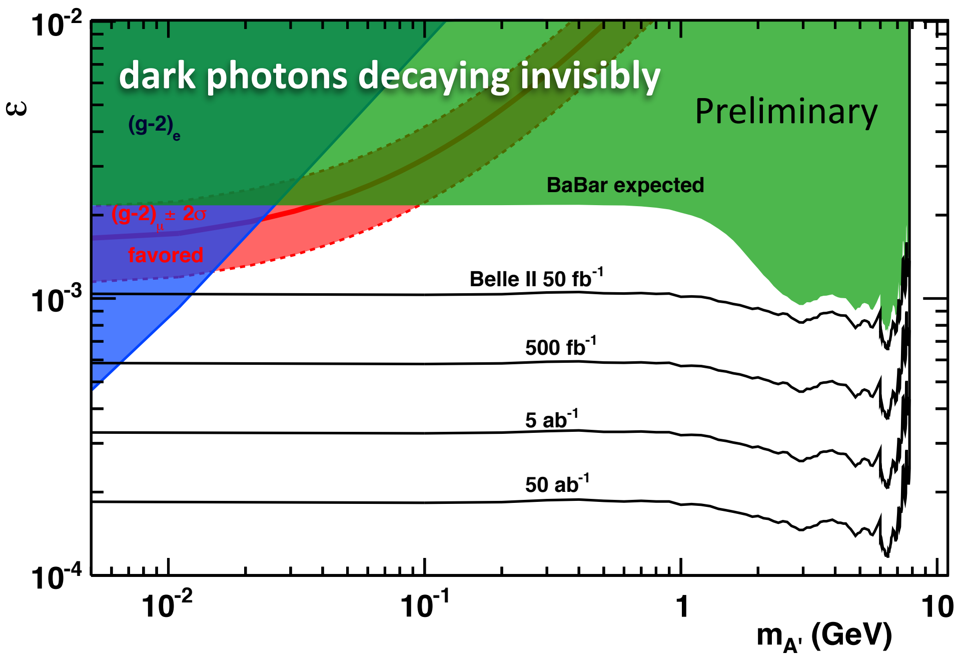


1. Υ(4S) is our core. Clear motivations to run mostly at Υ(4S) → see **Φ₃** projection.

2. *Quantitative* arguments for running non Υ(4S) [for a few weeks] will be seriously considered.

   Quarkonia(like) / **Υ(3S), Υ(6S), Scans**

   We won't decide the program in the report, only to provide physics cases**.**



3. **Dark sectors** and low multiplicity trigger limited at Belle may have good opportunities irrespective of E_{CM}.

B_s physics with $\Upsilon(5S)$ data

There are variety of semi-leptonic B_s decays, such as:

$$B_s \to D_s l\nu, \quad X_c l\nu, \quad K^{(*)} l\nu, \quad , X - ul\nu, \quad \tau\tau$$

To investigate further, it is necessary to estimate the efficiency for B_s full reconstruction. The working group will clarify the most interesting measurements from theory point of view and complementarity with B_d physics.

B_s physics with $\Upsilon(5S)$ data

$B_s \to \gamma\gamma$ is an interesting channel both for new physics and QCD. The SM prediction $Br(B_s \to \gamma\gamma) = (0.18 - 2.45) \times 10^{-6}$ is a factor of 10^{-3} smaller than the current experimental limit set with $120 fb^{-1}$ of data.

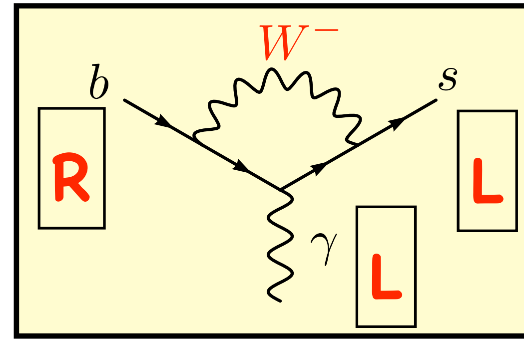
B_s physics with $\Upsilon(5S)$ data

- 2-Body Final Sate:
  The $B_s \to hh(h = \pi, K)$ decays with an emphasis on $B_s \to K^0 \overline{K}^0$.
- Quasi-2-Body Final Sate:
  $B_s \to \phi\pi^0$

Introduction:

the $b \to s\gamma$ as a window to BSM

Photon polarization of b→sγ modes



- The photon polarization of b →sγ process has an unique sensitivity to BSM with right-handed couplings.
- However, the photon polarization has never been measured at a hight precision so far: an important challenge for future experiments such as LHCb and Belle II.

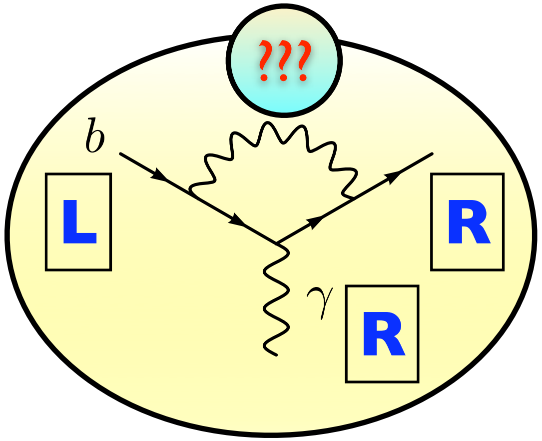
In SM

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

✍ b →s γ_L (left-handed polarization)

✍ $\bar{b} \rightarrow \bar{s}\, \gamma_R$ (right-handed polarization)

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.

Current status on the constraint on the right-handed contribution

We can write the amplitude including RH contribution as:

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

We have a constraint from inclusive branching ratio measurement:

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

While the polarization measurement carries information on

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

In this talk
$C'^{\rm NP}_{7\gamma}\neq 0$, $C^{\rm NP}_{7\gamma}=0$

Note: new physics contributions,
$C_{7\gamma}^{\rm NP}$ and/or $C'^{\rm NP}_{7\gamma}$ can be complex numbers!

Other scenarios, see
A. Tayduganov et al. JHEP 1208

How do we measure the polarization?!

proposed methods

- Method I: Time dependent CP asymmetry in $B_d \to K_S \pi^0 \gamma$, $K_S \pi^+ \pi^- \gamma$, $B_s \to K^+ K^- \gamma$ (called $S_{K_S \pi^0 \gamma}$, $S_{K_S \pi^+ \pi^- \gamma}$, $S_{K^+ K^- \gamma}$)
- 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 do we measure the polarization?!

proposed methods

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

  LHCb/Belle II
  $\sigma_{S_{K_S\pi\gamma}}(0.02)$

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

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

- Method III: $B \to K_1(\to K\pi\pi$…)

  LHCb/Belle II
  $\sigma_\lambda(0.1\text{-}0.2)$

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

Atwood et.al. PRL79

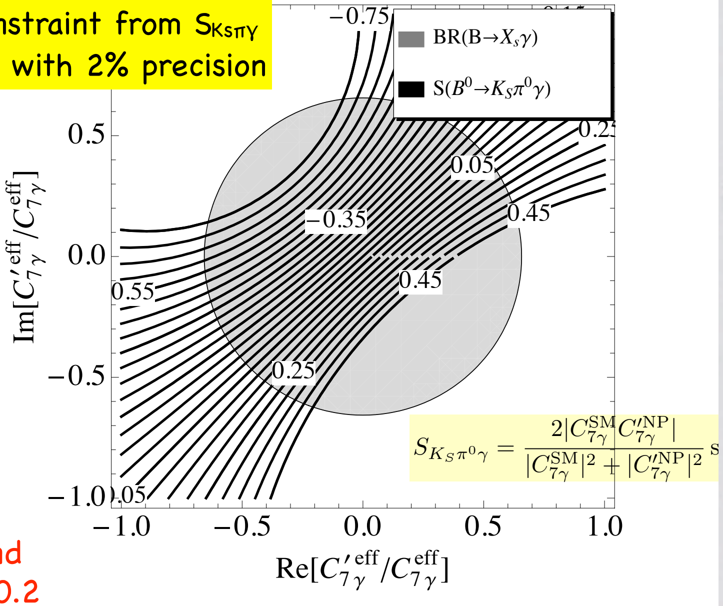
Kruger, Matias PRD71
Becirevic, Schneider, NPB854

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

Method I

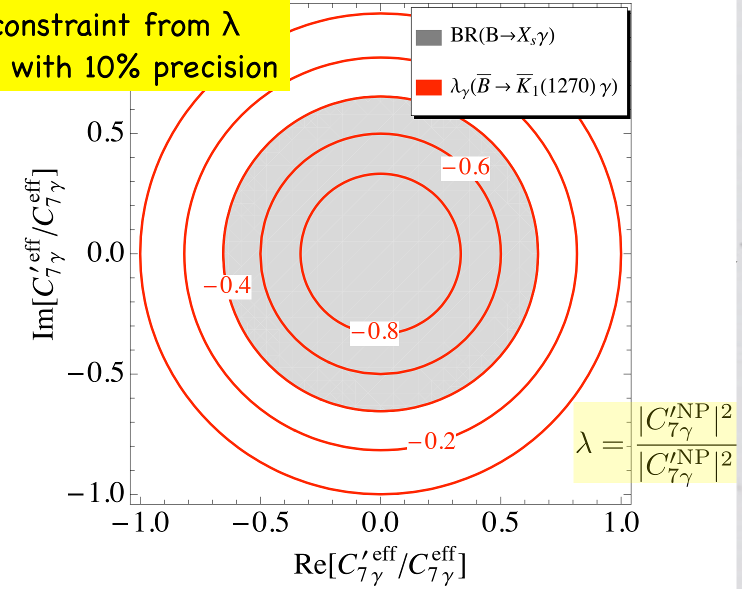
Expected constraint from $S_{K_S\pi\gamma}$ measurement with 2% precision



Current bound
$S_{K_S\pi^0\gamma}$ = -0.15±0.2

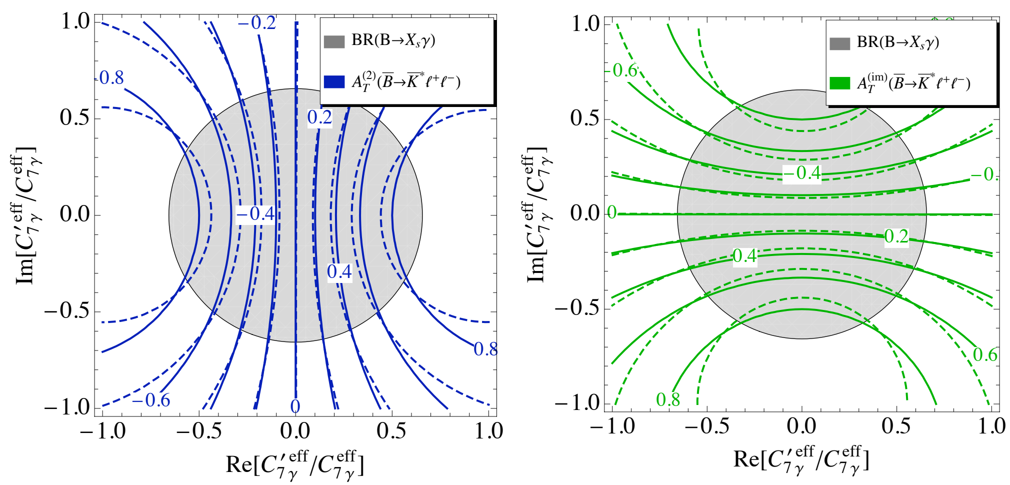
Method III

Expected constraint from λ measurement with 10% precision



Method II

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

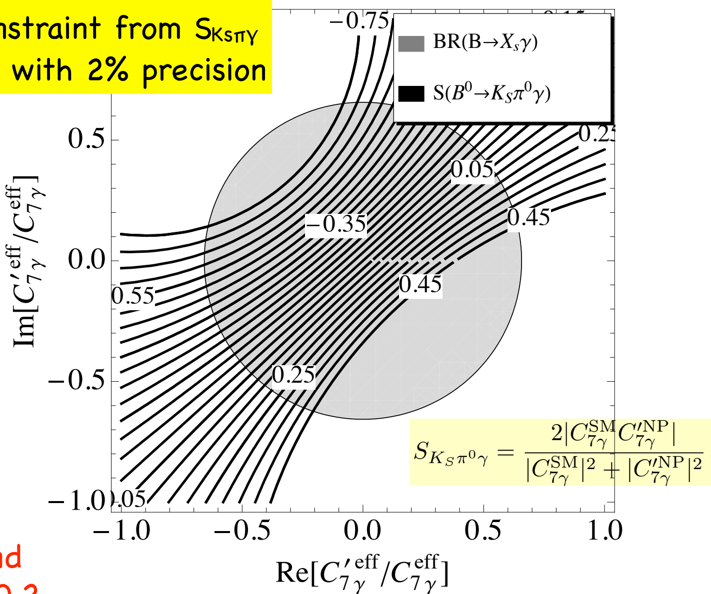


It out that Method I with $B_s \to K^+K^-\gamma$ gives similar constraints.

Becirevic, EK, Le Yaouanc, Tayduganov arXive: 1206.1502

Method I

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

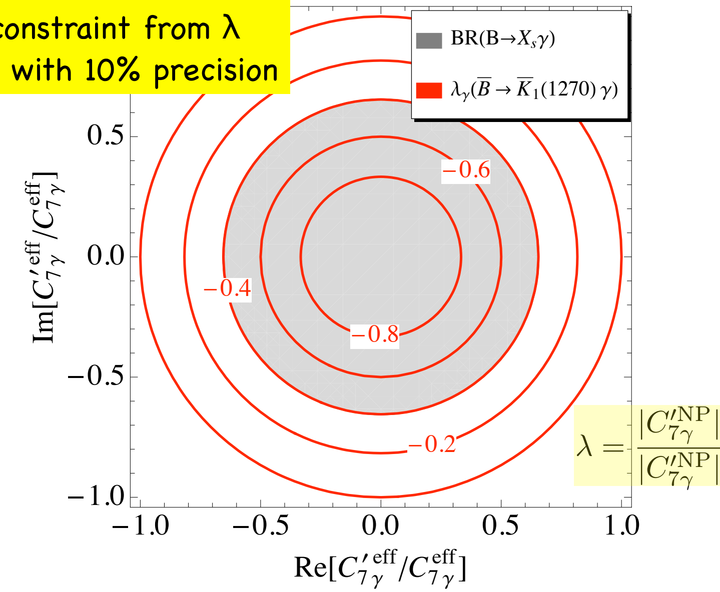


Current bound

$S_{K_S\pi^0\gamma}$ = -0.15±0.2

Method III

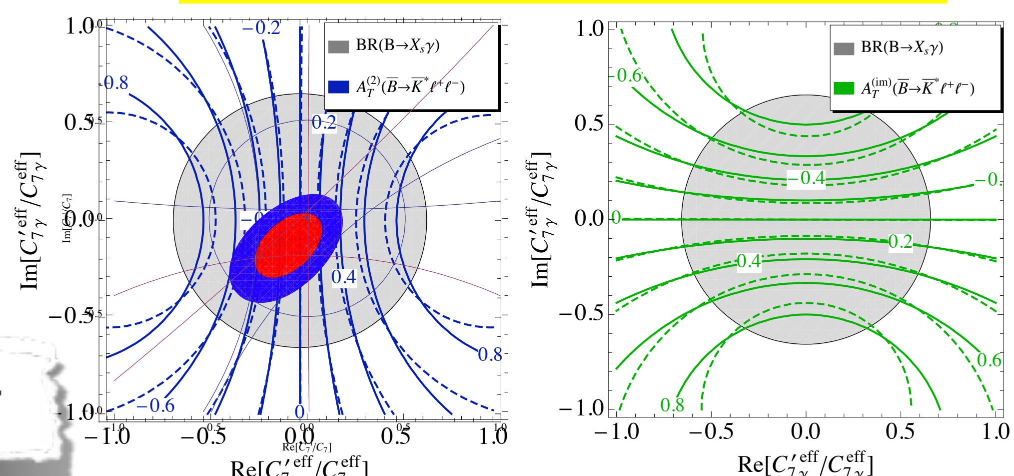
Expected constraint from λ measurement with 10% precision



Method II

Expected constraint from

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



LHCb measurement finally arrived!!!

It out that Method I with $B_s\to K^+K^-\gamma$ gives similar constraints.

Becirevic, EK, Le Yaouanc, Tayduganov arXive: 1206.1502

How do we measure the polarization?!

proposed methods

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

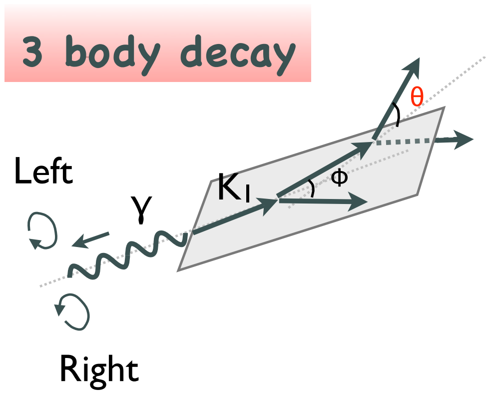
Gronau et al PRL88
E.K. Le Yaouanc, Tayduganov PRD83

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

Separation of $K\pi\pi$ resonances are essential for these studies.

Theoretical uncertainties for λ_γ

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



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

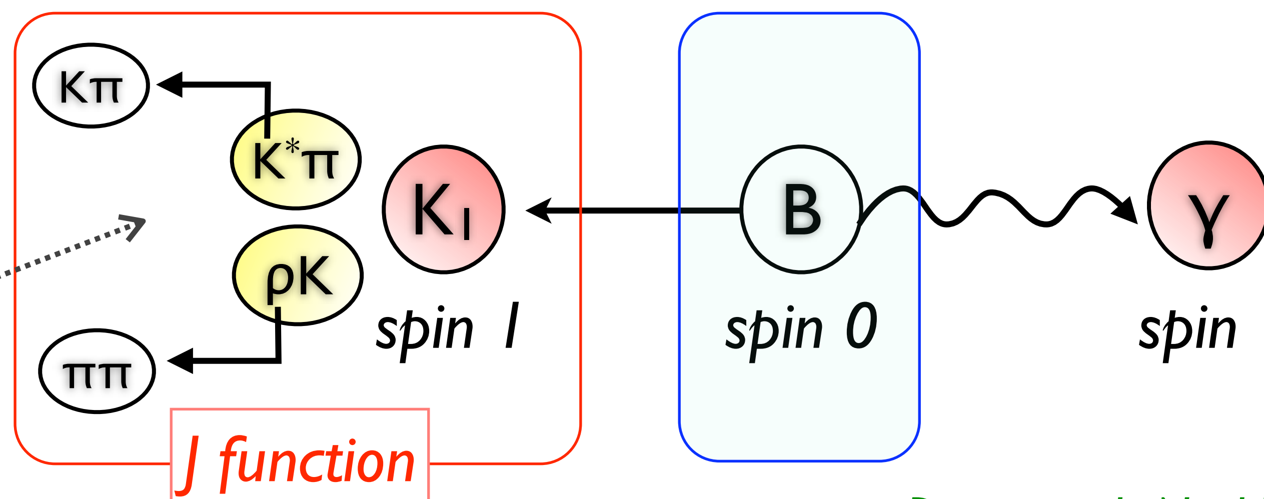
$$= \frac{3}{4} \frac{\langle Im(\hat{n}\cdot(\vec{J}\times\vec{J}^*))\rangle}{\langle|\vec{J}|^2\rangle} \frac{|c_R|^2 - |c_L|^2}{|c_R|^2 + |c_L|^2}$$

A= - 0.085
±0.019(stat)
±0.003(syst)

LHCb-CONF-2013-009

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

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



Source of imaginary part :
overlap of two Breite-Wigner

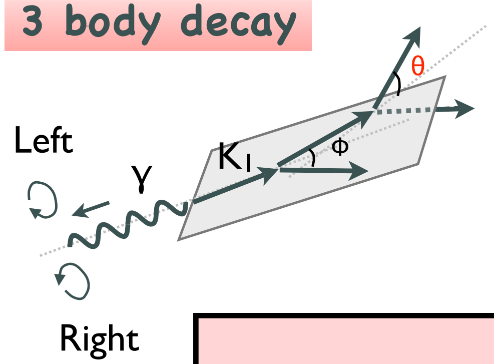
Daum et al, Nucl Phys, B187 ('81)
Thesis of S.Akar (Babar)

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

Theoretical uncertainties for λ_γ

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

3 body decay



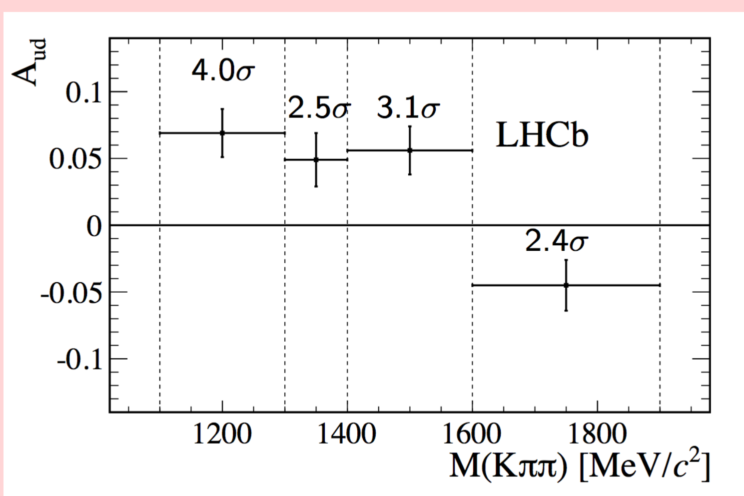
$$\mathcal{A} = \frac{\int_0^1 \cos\theta \frac{d\Gamma}{d\cos\theta} - \int_{-1}^0 \cos\theta \frac{d\Gamma}{d\cos\theta}}{\int_{-1}^1 \cos\theta \frac{d\Gamma}{d\cos\theta}}$$

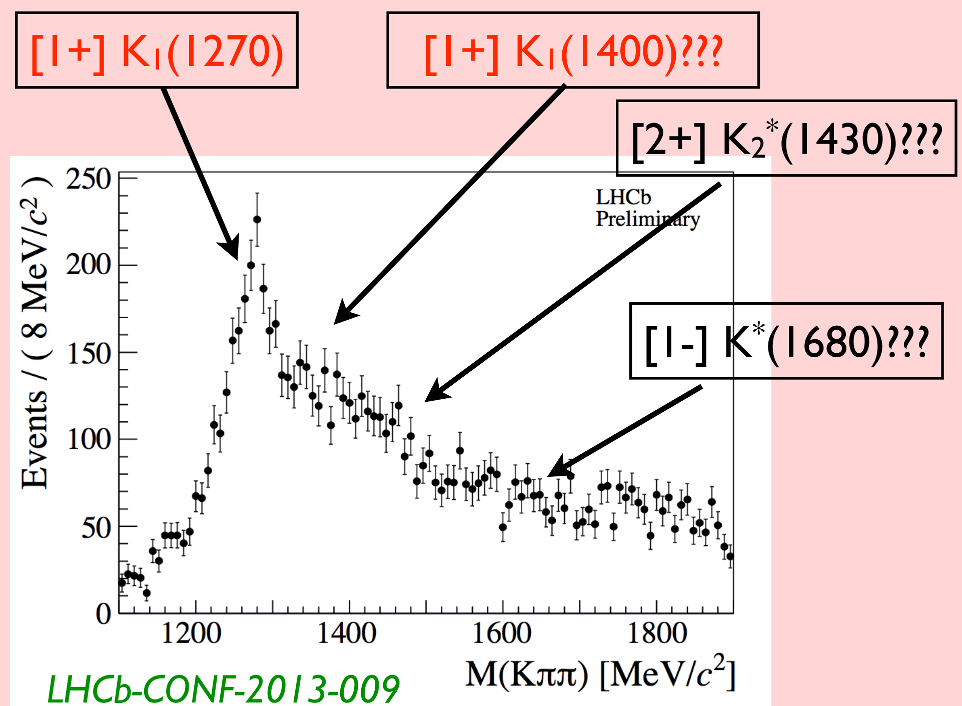
$$= \frac{3}{4} \frac{\langle Im(\hat{n}\cdot(\vec{J}\times\vec{J}^*))\rangle}{\langle|\vec{J}|^2\rangle} \frac{|c_R|^2 - |c_L|^2}{|c_R|^2 + |c_L|^2}$$

A= - 0.085
±0.019(stat)
±0.003(syst)

LHCb-CONF-2013-009

We need J function to interpret the LHCb result.





LHCb-CONF-2013-009

Sourc…

overlap…

('81)

…, 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)

A.Tayduganov, EK, Le Yaouanc, 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

1. Model independent extraction i.e. from c

tion

2. M

M

Proposition to LHCb/Belle II!

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

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

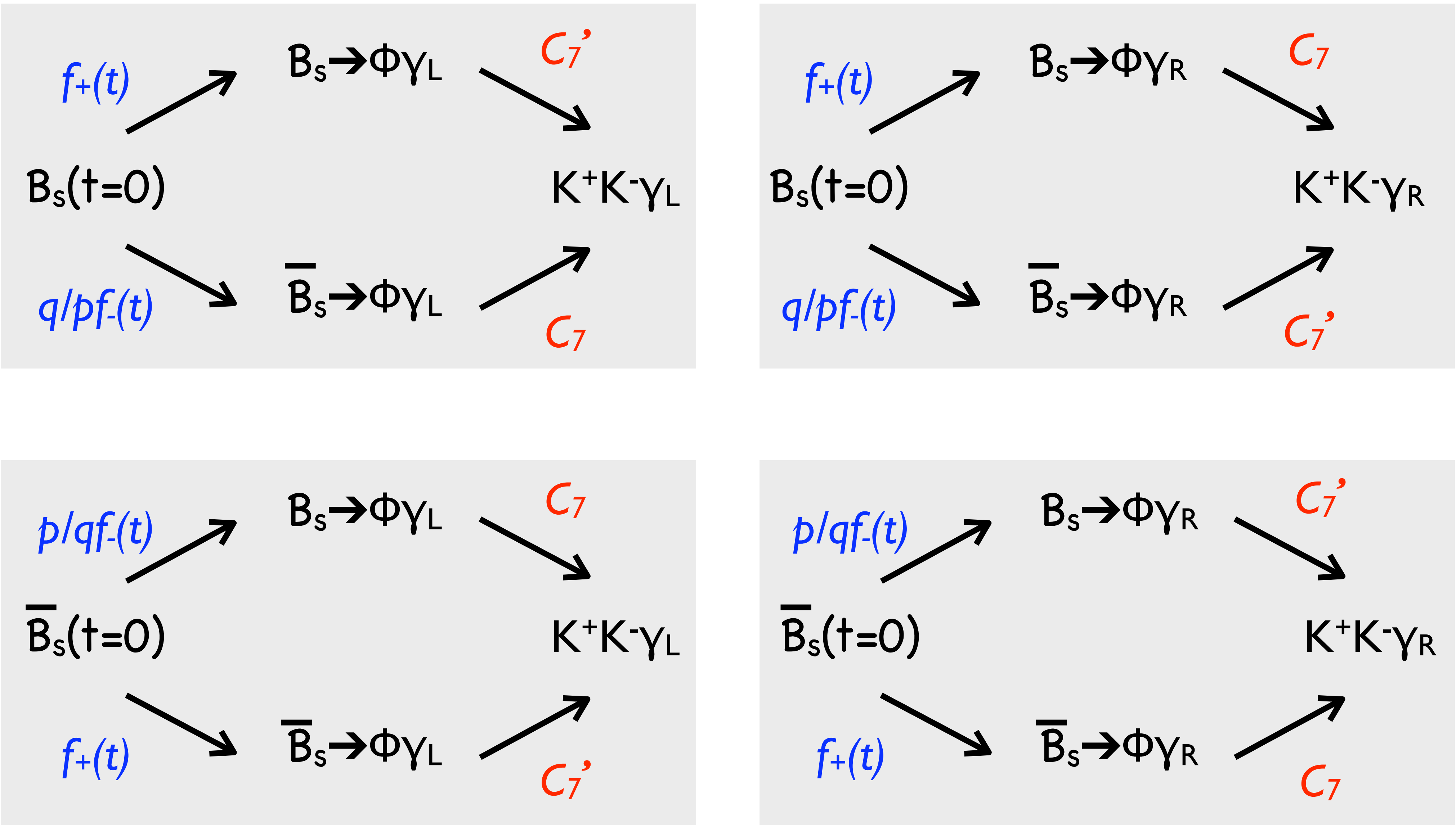
Davier, Duflot, Le Diberder, Rouge, PLB306 '93

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

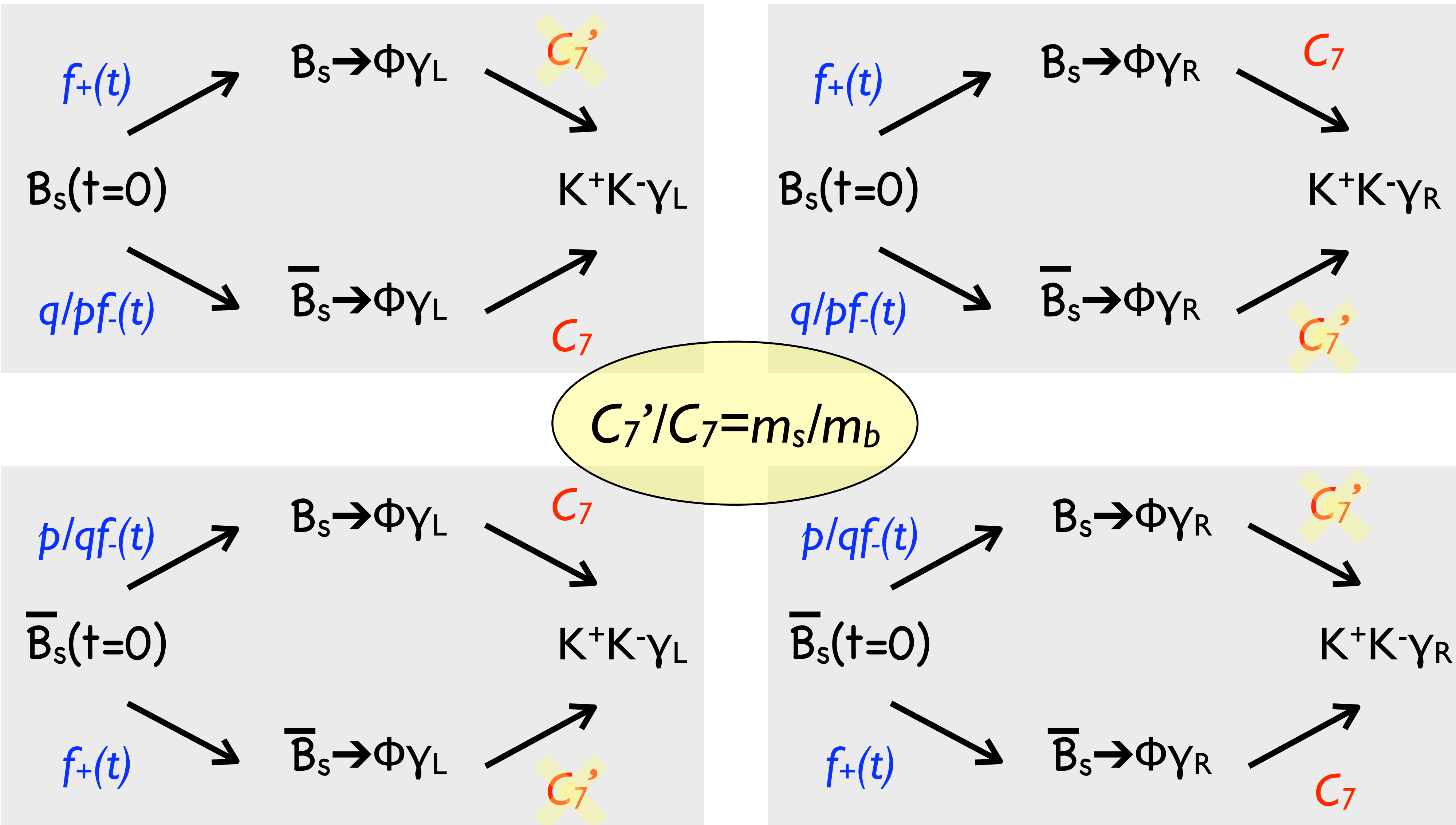
✓ When the PDF depends only linearly to the polarization parameter, one can simplify the analysis using the ω variable.

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

Photon polarization with TDCPV

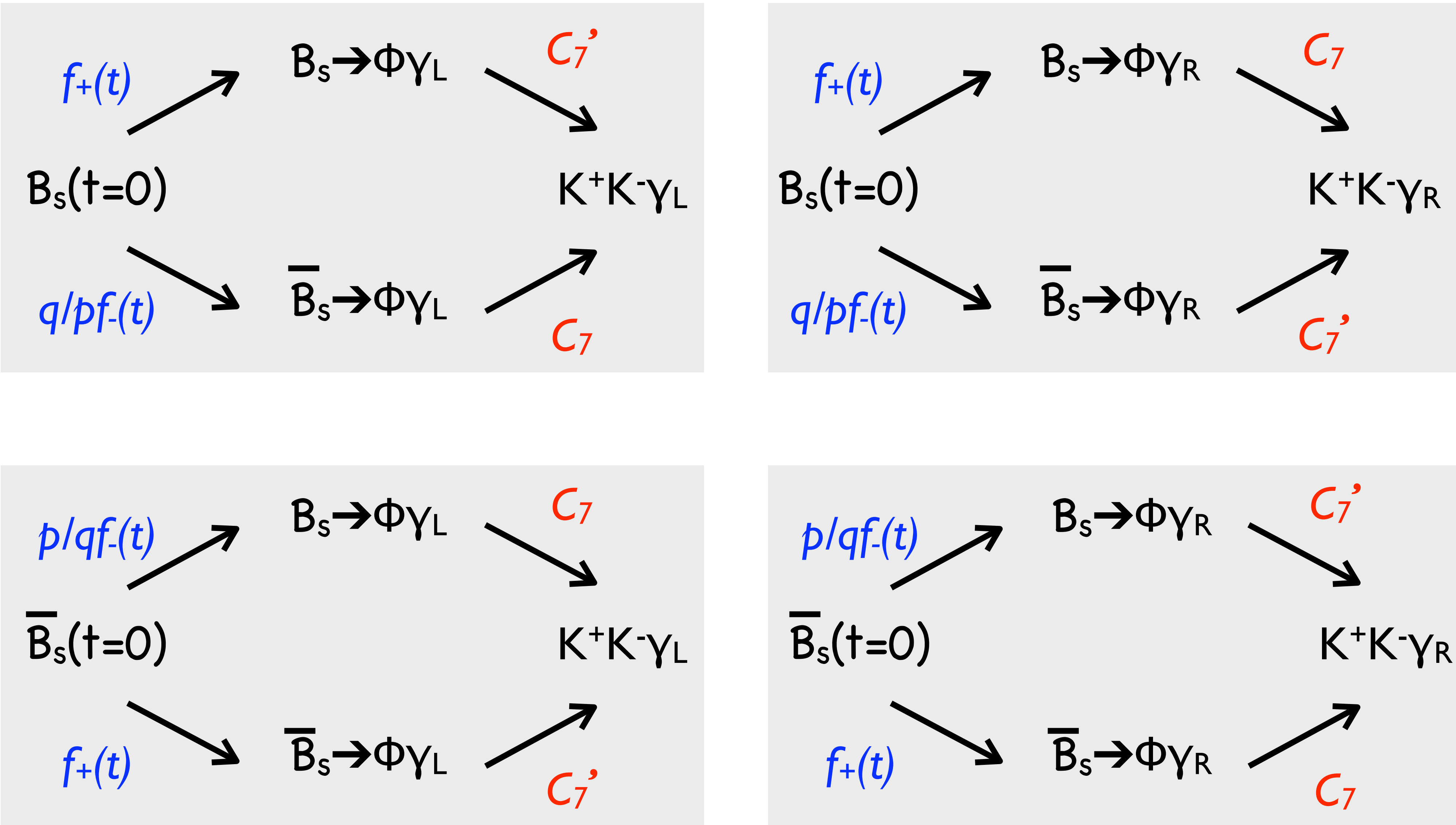


Photon polarization with TDCPV



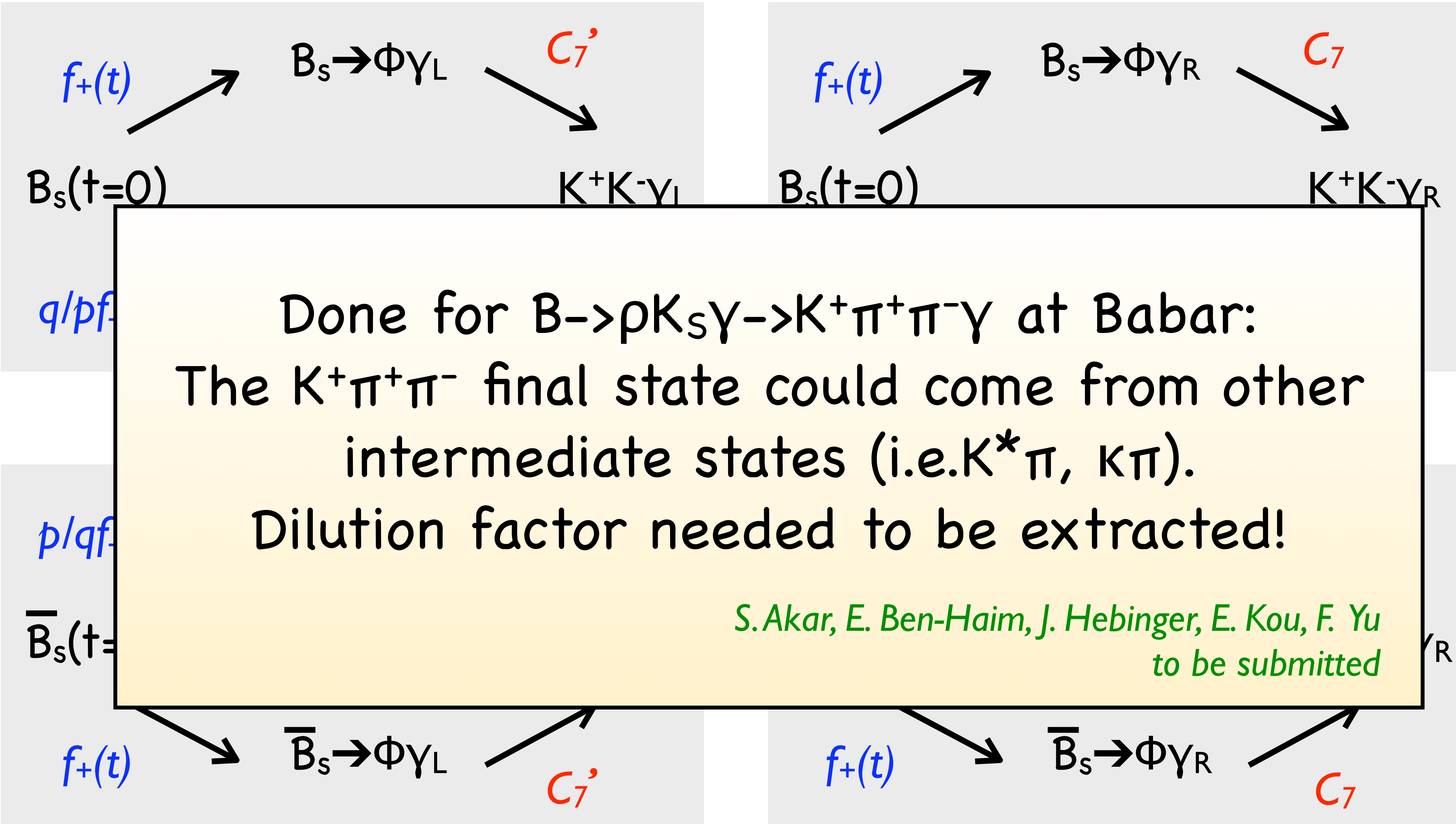
In SM, CP asymmetry suppressed.

Photon polarization with TDCPV



A large CP asymmetry = right-handed contributions

Photon polarization with TDCPV



Done for $B \to \rho K_S\gamma \to K^+\pi^+\pi^-\gamma$ at Babar:
The $K^+\pi^+\pi^-$ final state could come from other intermediate states (i.e. $K^*\pi$, $\kappa\pi$).
Dilution factor needed to be extracted!

S. Akar, E. Ben-Haim, J. Hebinger, E. Kou, F. Yu
to be submitted

A large CP asymmetry = right-handed contributions

Time-dependent decay rate of $B_s \to \Phi\gamma$

$$\Gamma_{B^0_{(s)}\to\Phi^{\mathcal{CP}}\gamma}(t) = |A|^2 e^{-\Gamma_{(s)}t}\left(\cosh\frac{\Delta\Gamma_{(s)}t}{2} + \mathcal{A}^{\Delta}\sinh\frac{\Delta\Gamma_{(s)}t}{2} + \mathcal{C}\cos\Delta m_{(s)}t + \mathcal{S}\sin\Delta m_{(s)}t\right)$$

$$\Gamma_{\bar{B}^0_{(s)}\to\Phi^{\mathcal{CP}}\gamma}(t) = |\overline{A}|^2 e^{-\Gamma_{(s)}t}\left(\cosh\frac{\Delta\Gamma_{(s)}t}{2} + \overline{\mathcal{A}}^{\Delta}\sinh\frac{\Delta\Gamma_{(s)}t}{2} + \overline{\mathcal{C}}\cos\Delta m_{(s)}t + \overline{\mathcal{S}}\sin\Delta m_{(s)}t\right)$$

○ :Untagged ○ :Tagged

Useful to study charm contributions ?!?!

For B_s

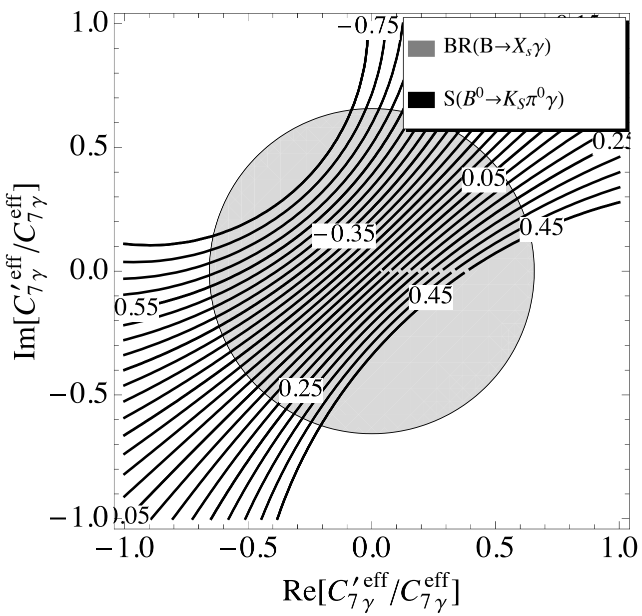
$$|A|^2 : |A|^2\left(1+\left|\frac{q}{p}\overline{\rho}\right|^2\right) \quad \mathcal{A}^{\Delta} : \frac{-2\mathrm{Re}\left(\frac{q}{p}\overline{\rho}\right)}{1+|\frac{q}{p}\overline{\rho}|^2} \quad \mathcal{C} : \frac{1-\left|\frac{q}{p}\overline{\rho}\right|^2}{1+\left|\frac{q}{p}\overline{\rho}\right|^2} \quad \mathcal{S} : \frac{-2\mathrm{Im}\left(\frac{q}{p}\overline{\rho}\right)}{1+\left|\frac{q}{p}\overline{\rho}\right|^2}$$

- Oscillation part (q/p) might be the same as e.g. $B_s \to J/\psi\Phi$.
- Decay part ($\overline{\rho}$) is sensitive to C_7'/C_7 !

Expected constraints on C_7'/C_7 by S and A^{Δ}

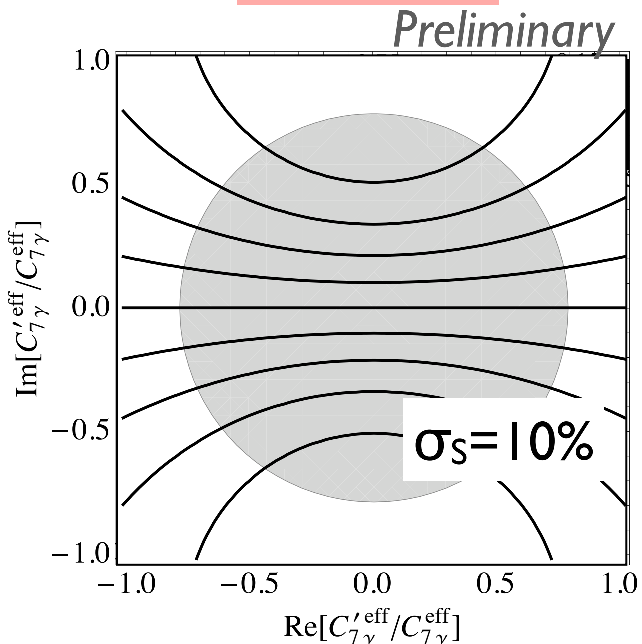
J. Hebinger and E.K in preparation

$S_{K_s\pi^0\gamma}$

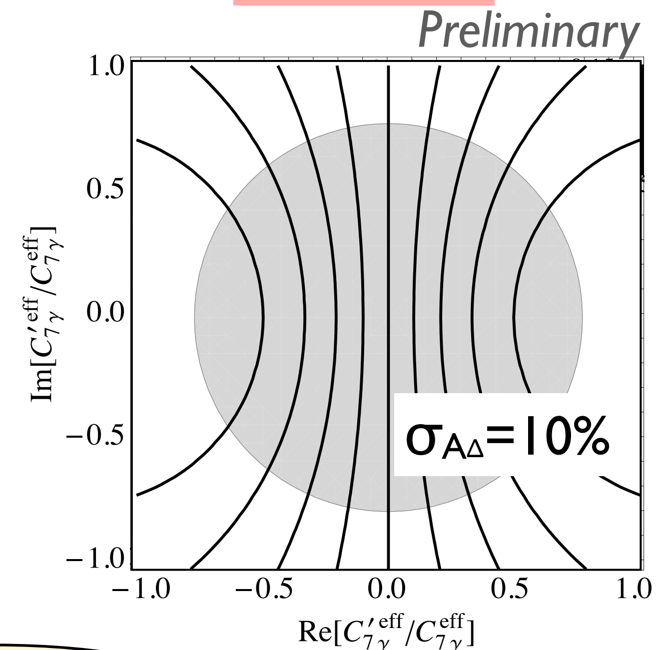


BELLE II

$S_{K^+K^-\gamma}$



$A^{\Delta}_{K^+K^-\gamma}$

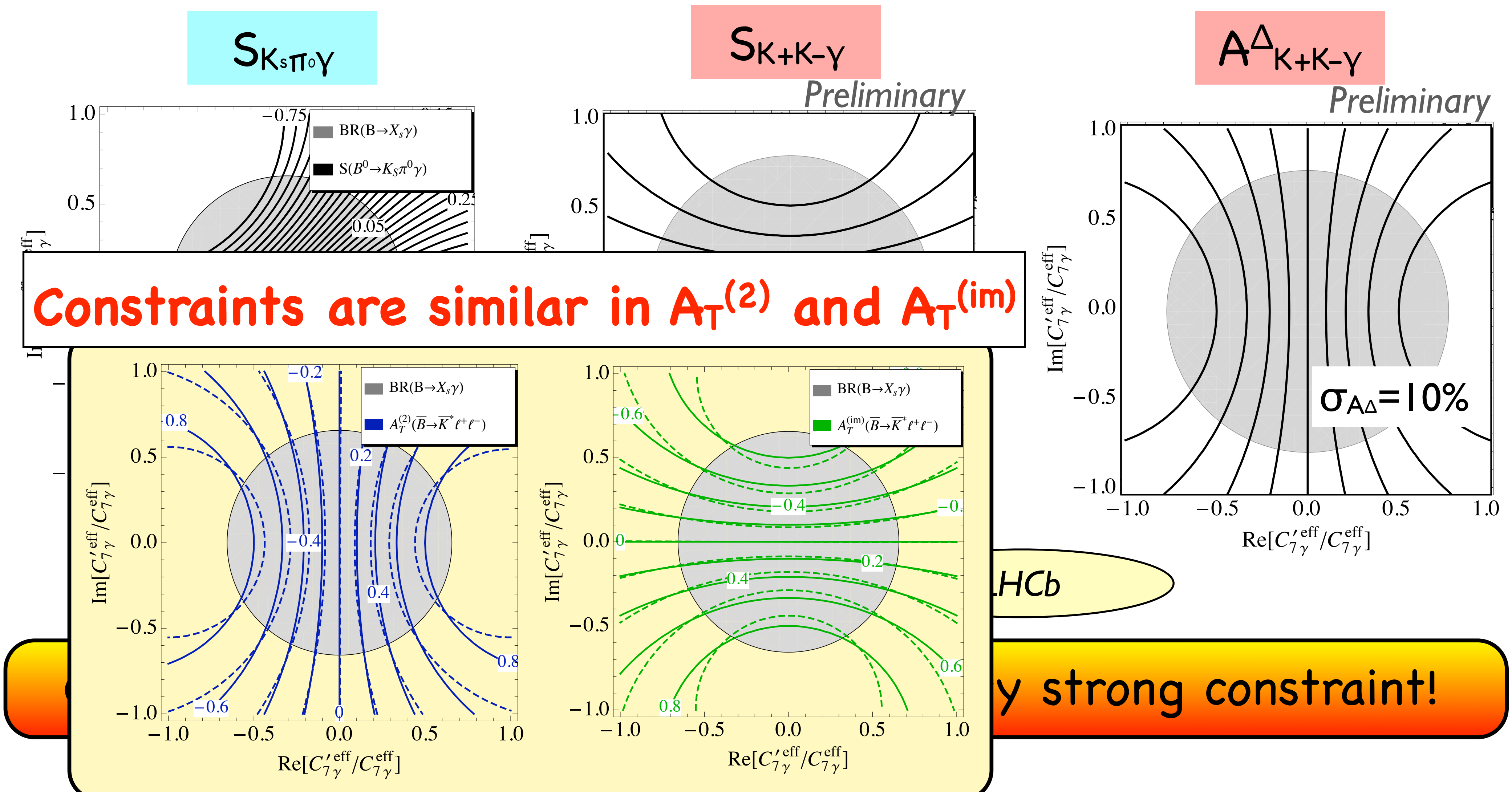


LHCb

Combining S and A^{Δ}, we can obtain a very strong constraint!

Expected constraints on C_7'/C_7 by S and A^{Δ}

J. Hebinger and E.K in preparation



Theoretical Uncertainties

Theoretical uncertainties for $S_{K_S\pi^0\gamma}$

Becirevic, EK, Le Yaouanc, Tayduganov, JHEP 1208

- The term m_s/m_b in SM, which is about 2 %. Similar order to the experimental precision achievable at 50 ab^{-1}
- The uncertainties in the oscillation phase, Φ_1. Current experimental error can induce about 1-2% but it can be improved in the future.
- Charm penguin, 2% OR 10%?!

$$\mathcal{M}(\overline{B}\to\overline{K}^*\gamma) = -\frac{4G_F}{\sqrt{2}}V_{tb}V_{ts}^*\langle\overline{K}^*\gamma|C_{7\gamma}\mathcal{O}_{7\gamma}+C'_{7\gamma}\mathcal{O}'_{7\gamma} + i\varepsilon_\gamma^{\mu*}\sum_{i\neq 7\gamma}C_i\int d^4x e^{iqx}T\{j_\mu^{\text{e.m.}}(x)\mathcal{O}_i(0)\}|\overline{B}\rangle\,,$$

Discussed in detail at B2TiP...

QCD sum-rule

Khodjamirian et al Phys. Lett.B('97)
Ball and Zwicky Phys. Lett B ('06)

Add gluon to charm line and expand in terms of $1/m_c$

$$\mathcal{O}_F = i\varepsilon_\gamma^{\mu*}\int d^4x e^{iqx}T\{[\overline{c}(x)\gamma_\mu c(x)]\mathcal{O}_2(0)\} = -\frac{1}{48\pi^2 m_c^2}(D^\rho F^{\alpha\beta})[\overline{s}\gamma_\rho(1-\gamma_5)g_s\tilde{G}^a_{\alpha\beta}t^a b] + \ldots$$

$$C_L = C_{7\gamma}^{(0)eff}(m_b) - C_2^{(0)}(m_b)\frac{L+\tilde{L}}{36 m_b m_c^2 T_1^{(K^*)}(0)}$$

$$C_R = C_{7\gamma}^{\prime(0)eff}(m_b) - C_2^{(0)}(m_b)\frac{L-\tilde{L}}{36 m_b m_c^2 T_1^{(K^*)}(0)}$$

$$L = (0.2\pm 0.1)\ \text{GeV}^3, \qquad \tilde{L} = (0.3\pm 0.2)\ \text{GeV}^3$$

$$\frac{\mathcal{M}(\overline{B}\to\overline{K}^*\gamma_R)}{\mathcal{M}(\overline{B}\to\overline{K}^*\gamma_L)} \simeq \frac{m_s}{m_b}\times(0.8\pm 0.2)\simeq 2\%\,.$$

SCET

Grinstein et al Phys. Rev. D('06)

Add gluon to charm line, then the counting low leads to a contribution at $1/m_c=0$

$$\frac{\mathcal{M}(\overline{B}\to\overline{K}^*\gamma_R)}{\mathcal{M}(\overline{B}\to\overline{K}^*\gamma_L)} \sim \frac{(C_2/3)}{C_{7\gamma}}\frac{\Lambda_{\text{QCD}}}{m_b}\sim 10\%\,.$$

The loop diagram can be expanded in terms of $z=1/m_c^2$

Tayduganov et al JHEP ('12)

$$\kappa(z) = \frac{1}{2}-\frac{2}{z}\arctan^2\left[\sqrt{\frac{z}{4-z}}\right] = -\frac{z}{24}-\frac{z^2}{180}-\frac{z^3}{1120}+\ldots\,.$$

Then the leading term leads to $1/12m_c^2$

$$\frac{\mathcal{M}(\overline{B}\to\overline{K}^*\gamma_R)}{\mathcal{M}(\overline{B}\to\overline{K}^*\gamma_L)} \sim \frac{(C_2/3)}{C_{7\gamma}}\frac{\Lambda}{m_b}\times\frac{1}{12}\frac{\Lambda m_b}{m_c^2}$$

Outlook

- Many efforts have been and will be made to measure the photon polarization of the $b \to s\gamma$ process at Belle II and LHCb.
- Theoretical uncertainties, especially from charm contribution are still under debate and it is important to continue discussion on this issue.
- We are working on interpreting the LHCb result on the asymmetry of the $B \to K\pi\pi\gamma$ channel based on our theoretical model for K_1 strong decay. But eventually, the simultaneous measurement with $B \to K_1 J/\psi$ would be the best way to remove the hadronic uncertainties.
- We are investigating other channels to measure the photon polarization. So far, we see some difficulties on $B \to VP\gamma$ channel but hopefully, we can find some way out.

Backup

Constraint of magnetic operator

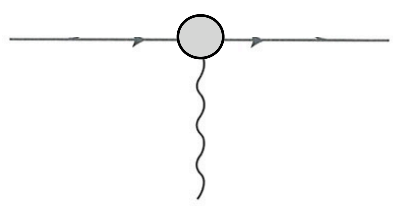
The $b \to s\gamma$ is induced by the electro-magnetic operator. The constraint on the coupling c_{ij} and new physics scale Λ depend on the chiral structure.

For $b \to s\gamma$: $i=2, j=3$

SM coupling
$G_F m_b (V_{tb} V_{ts}^*) e$

$$\frac{c_{ij}}{\Lambda} e \overline{\psi}_{iA} \sigma^{\mu\nu} \psi_{jB} F_{\mu\nu}$$

ij=generation, A, B: L or R



	NP contribution		
The new physics has same Dirac/flavour structure as the SM	$m_b\, c_{23} (V_{tb} V_{ts}^*) e/\Lambda$	$Br_{SM} > Br_{NP}$, $\Lambda = 1$ TeV	$c_{23} < O(10^{-2})$
The new physics has same Dirac/flavour structure but "chirally-enhanced"	$m_t\, c_{23} (V_{tb} V_{ts}^*) e/\Lambda$	$Br_{SM} > Br_{NP}$, $\Lambda = 1$ TeV	$c_{23} < O(10^{-3})$
The new physics is "right-handed"	$m_t\, c_{23} (V_{tb} V_{ts}^*) e/\Lambda$	$Br_{SM} > Br_{NP}$, $\Lambda = 1$ TeV	$c_{23} < O(10^{-5})$

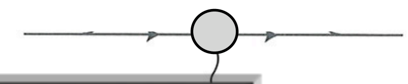
SM coupling $G_F m_s (V_{tb} V_{ts}^*) e$

Constraint of magnetic operator

The b->sγ is induced by the electro-magnetic operator. The constraint on the coupling c_{ij} and new physics scale Λ depend on the chiral structure.

For b->sγ: i=2, j=3

$$\frac{c_{ij}}{\Lambda} e\overline{\psi}_{iA}\sigma^{\mu\nu}\psi_{jB}F_{\mu\nu}$$



SM coupling

$G_F m_b($

The ne… same … struct…

$<O(10^{-2})$

Even if the coupling is strongly constrained by other b->s transitions (e.g. Bs oscillation), New Physics contributions with new Dirac/flavour/chiral structures can lead to a large contribution, observable in the future!

The new Dirac/flavour structure but "chirally-enhanced"

$m_t\, c_{23}(V_{tb}V_{ts}^*)e/\Lambda$

Λ= 1 TeV

$c_{23}<O(10^{-3})$

NP contribution

The new physics is "right-handed"

$m_t\, c_{23}(V_{tb}V_{ts}^*)e/\Lambda$

$Br_{SM}>Br_{NP}$

Λ= 1 TeV

$c_{23}<O(10^{-5})$

SM coupling $G_F m_s(V_{tb}V_{ts}^*)e$

Current status on the constraint on the right-handed contribution

A.Tayduganov et al. JHEP 1208

(a) assume
$Re[C(')_{7\gamma}^{NP}] \neq 0$
$Im[C(')_{7\gamma}^{NP}] = 0$

(b) assume
$C'_{7\gamma}{}^{NP} \neq 0$
$C_{7\gamma}^{NP} = 0$

(c) assume
$C'_{7\gamma}{}^{NP} = C_{7\gamma}^{NP}$

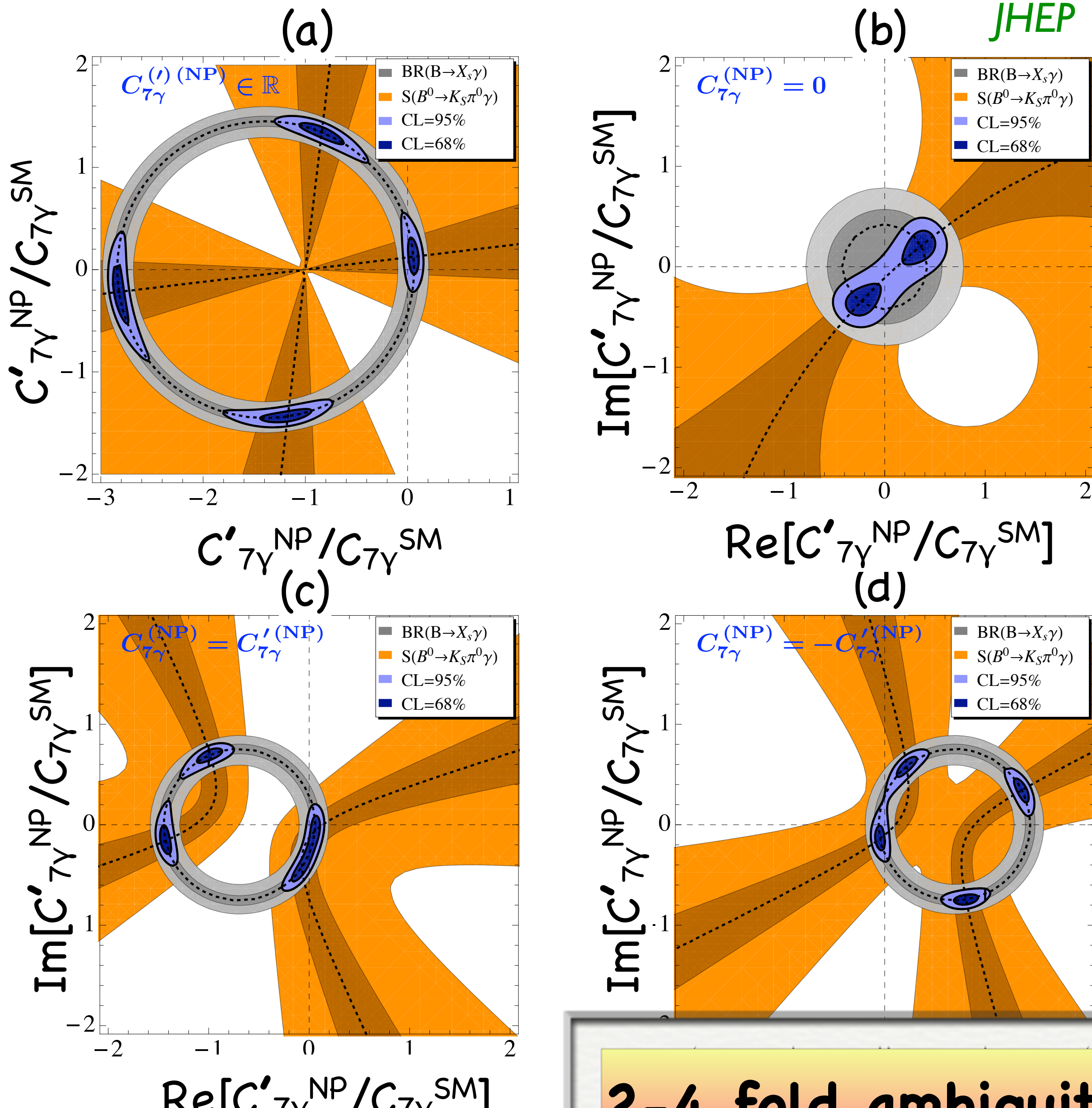
(d) assume
$C'_{7\gamma}{}^{NP} = -C_{7\gamma}^{NP}$

CONSTRAINTS:

:Br(B->XsY)

:$S_{CP}(B\to K_s\pi^0\gamma)$

:combined



2-4 fold ambiguities...

BSM Discovery Channels

- Tee level Charged Higgs [tanbeta-MH±]
  - WG1: B -> tau nu, mu nu
  - WG1: B -> D(*) tau nu (R ratio, q2 dependence, angular distribution)
- NP in b-> s/d penguins [C7(‘), C9(‘), C10(‘) fit]
  - WG 2: B-> Xs/d gamma CP violation and BR
  - WG 2/3: Time-dependent CP for B-> Ks pi0 gamma, rho gamma
- NP in b-> u trees w/wo CP
  - WG1: B -> Xu l nu
  - WG1: |Vub| determination with B-> pi l nu
  - WG1: WG1: B -> tau nu, mu nu
  - WG3: Time dependent CP in B-> pipi, pi rho, rho rho
- NP in b-> s penguins
  - WG 3: Time-dependent CP for B-> phi Ks, eta’ Ks, pi0 Ks, KsKsKs
  - WG4: phi3 measurement with B-> K pi
  - WG5: charmless 2/3 bodies: B -> K*pi, K rho, phi K*, K*rho, VV, KKK, KKpi, Kpipi
- NP in b-> d penguins
  - WG3: Time dependent CP in B-> pipi, pi rho, rho rho
- NP in b-> c trees w/wo CP [Right-handed W?]
  - WG1: B -> Xc l nu
  - WG4: phi3 measurement via GLW, ADS, GGSZ, GLS methods
- NP CP in b-> d box
  - WG3: Time dependent CP in B-> J/psi Ks

BSM Discovery Channels

- Lepton universality violation
  - WG 2: Lepton Universality in B-> Xs l+l- (l=e, mu)
- Lepton flavour violation
  - WG8: tau -> 3mu
- CP violation in lepton sector
  - WG8: CP violation in tau -> Kspi nu
- Light-Higgs
  - WG7/8: Y(3S) to photon + leptons
- Dark matter
  - WG7/8: ISR e+e- ---> photon nothing
- CPV in charm mixing
  - WG6: Time dependent CP in D->KKK, K pipi, pipipi
- CPV in charm decay
  - WG6: Direct CP asymmetry in D->pipi.KK
- Rare charm decay
  - WG6: D-> l nu, Ds-> l nu
  - WG6: D-> K(*)lnu, D-> rho gamma, phi gamma, gamma gamma, D->missing + gamma/pi

Competition!

https://d2comp.kek.jp/record/234

BELLE2-NOTE-PH-2015-004

Talk by Vagnoni

start 2021

LHC era		HL-LHC era		
Run 1 (2010-12)	Run 2 (2015-18)	Run 3 (2020-22)	Run 4 (2025-28)	Run 5+ (2030+)
3 fb^{-1}	8 fb^{-1}	23 fb^{-1}	46 fb^{-1}	100 fb^{-1}

b-, c- quark σ scale linear with √s

Run-2 50% less efficient for hadronic triggered modes

Run-3 will have a new trigger: recovering efficiency loss in hadron trigger, no change for muon triggers.