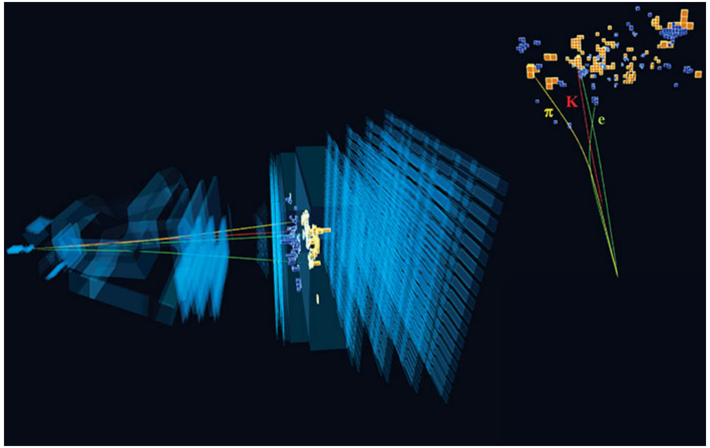
Measurement of photon polarisation in b→ sγ transitions

Marie-Hélène Schune
IJCLab, Orsay

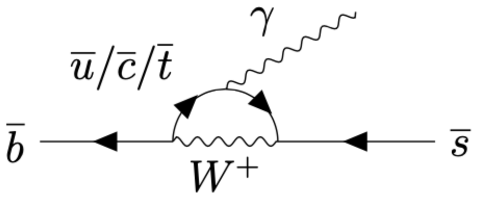


All plots and results from the LHCb publication arXiv:2010.06011 (submitted to JHEP)

IJCLab Irène Joliot-Curie
Laboratoire de Physique des 2 Infinis

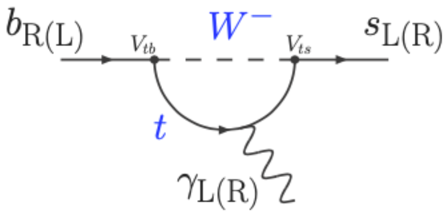
Why studying b→ sγ ?

In the SM:



FCNC: sensitive to NP

Polarisation:

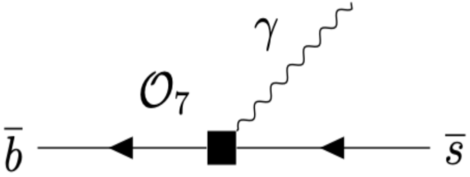


In the SM the γ is mostly left-handed

a right-handed signal would be a sign of NP

Why studying b→ sγ ?

In the SM:



Effective Hamiltonian description

$$\mathcal{H}_{\text{eff}} \simeq -\frac{4G_F}{\sqrt{2}} V_{tb} V_{ts}^{*} \left(C_7 O_7 + C_7' O_7' \right)$$

$$\frac{C_7'}{C_7} \simeq \frac{A_R}{A_L} \simeq \frac{m_s}{m_b} \simeq 0.02$$

Inclusive branching ratio: $\mathrm{BR} \propto (C_7^{\mathrm{SM}} + C_7^{\mathrm{NP}})^2 + (C_7'^{\,\mathrm{NP}})^2$ B-Factories

Main options to measure A_R/A_L

1. Time dependent rate of $\mathbf{B^0_{d,s} \to f_{CP}\gamma}$

$B^0 \to K^{*0}(\to K^0_S\pi^0)\gamma$ or $B^0_s \to \phi(\to K^+K^-)\gamma$

$$\bar{B} \to f_{CP}\gamma_L + \epsilon f_{CP}\gamma_R$$

$$\bar{B} \to B \to f_{CP}\gamma_R + \epsilon f_{CP}\gamma_L$$

interference

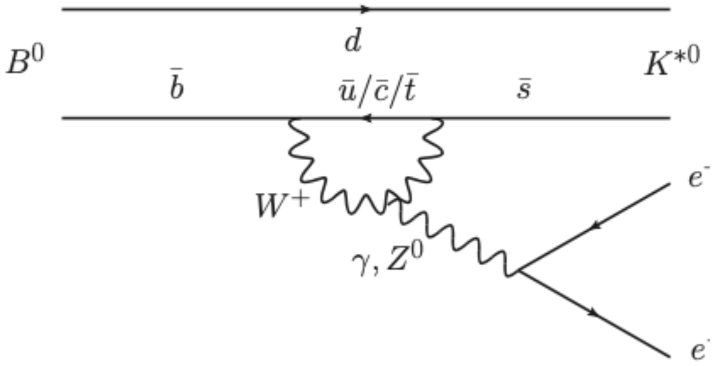
$$\overset{(-)}{\mathcal{B}}(t) = \mathcal{B}_0 e^{-\Gamma t}\left(\cosh\frac{\Delta\Gamma t}{2} - \mathcal{A}^\Delta \sinh\frac{\Delta\Gamma t}{2} \pm \mathcal{C}\cos(\Delta m\, t) \mp \mathcal{S}\sin(\Delta m\, t)\right)$$

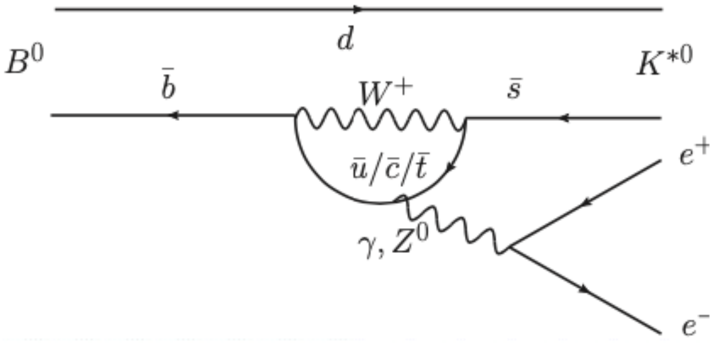
$$\mathcal{S} \approx \xi\frac{2\mathcal{I}m[e^{-i\phi_q}\,\mathcal{C}_7\mathcal{C}_7'|}{|\mathcal{C}_7|^2 + |\mathcal{C}_7'|^2} \qquad \mathcal{A}^\Delta \approx \xi\frac{2\mathcal{R}e[e^{-i\phi_s}\,\mathcal{C}_7\mathcal{C}_7'|}{|\mathcal{C}_7|^2 + |\mathcal{C}_7'|^2}$$

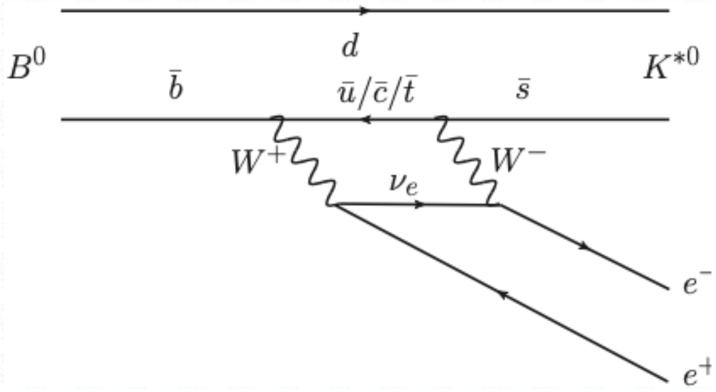
$\phi_d = 2\beta$
$\phi_s \sim 0$

IJCLab Irène Joliot-Curie Laboratoire de Physique des 2 Infinis

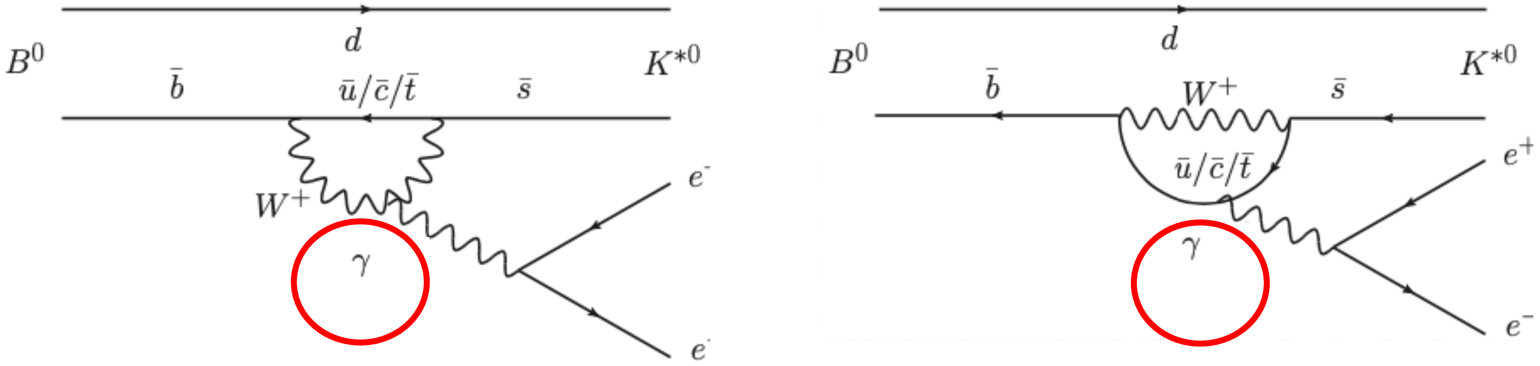
2. Angular analysis of $\mathbf{B_d^0} \rightarrow \boldsymbol{K^{*0} e^+ e^-}$ at very low q²







2. Angular analysis of $\mathbf{B_d^0} \rightarrow K^{*0} e^+ e^-$ at very low-q^2

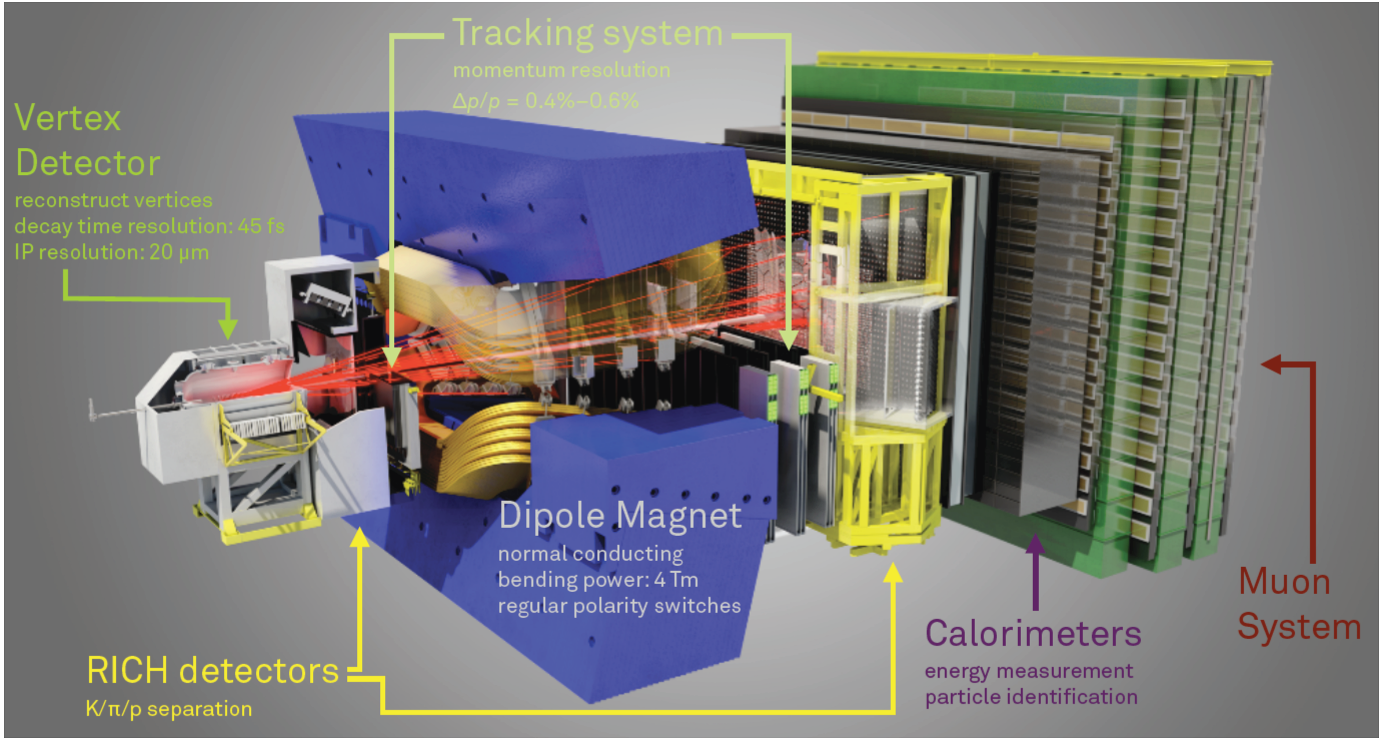


At very low-q^2 the diagrams with a virtual photon dominate

$q^2 = m^2(e^+ e^-)$

Which data ?

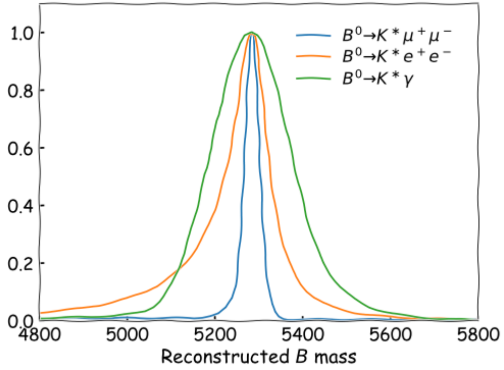
Full LHCb dataset (~ 10^{12} bb in detector acceptance):
3 fb^{-1} at 7 and 8 TeV, 6 fb^{-1} at 13 TeV



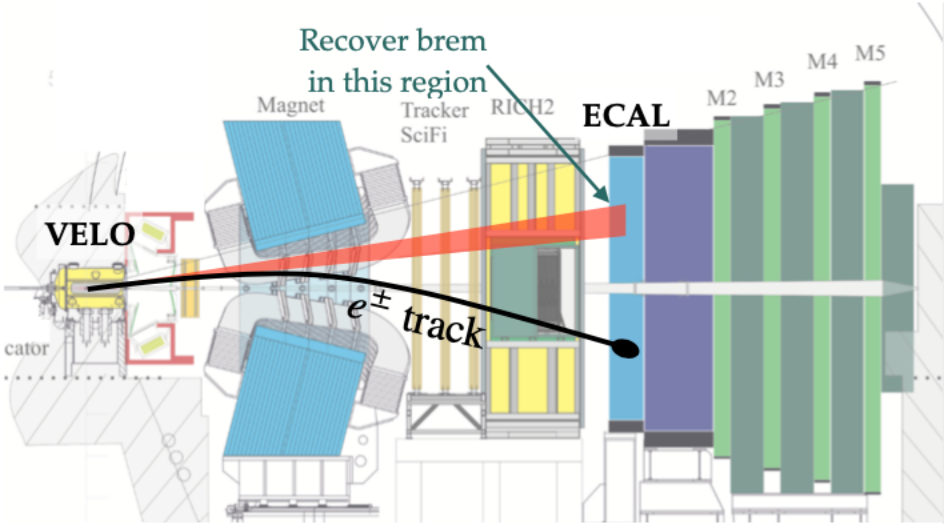
IJCLab Irène Joliot-Curie
Laboratoire de Physique des 2 Infinis

At LHCb:

- events are busy (hardware trigger needed)
- best reconstruction for $\mu^{\pm}$, $\pi^{\pm}$, $K^{\pm}$, p anti-p
- electrons emit quite a fair amount of bremsstrahlung before the magnet (recovery procedure efficiency ~ 50 %)

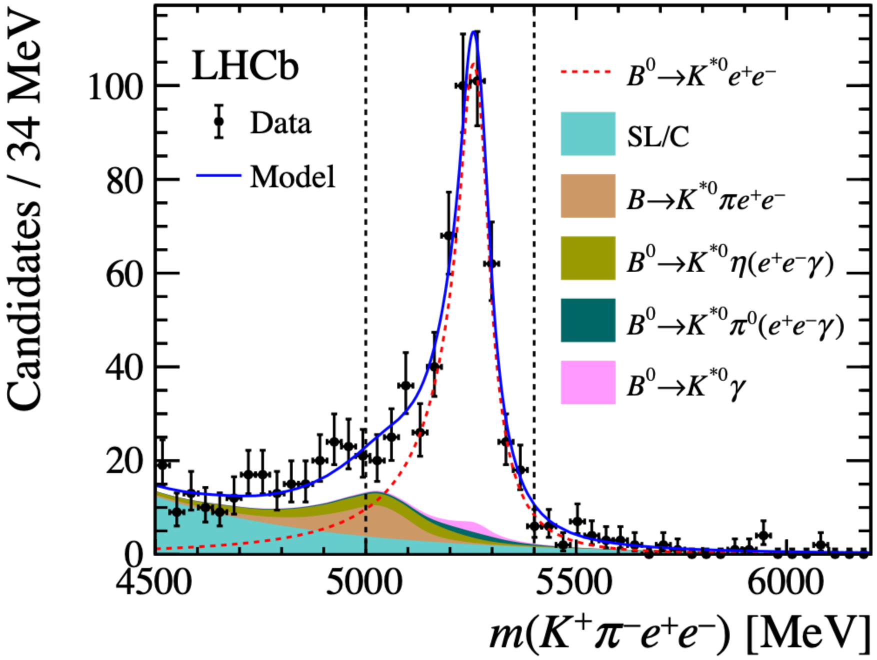


From M. Borsato



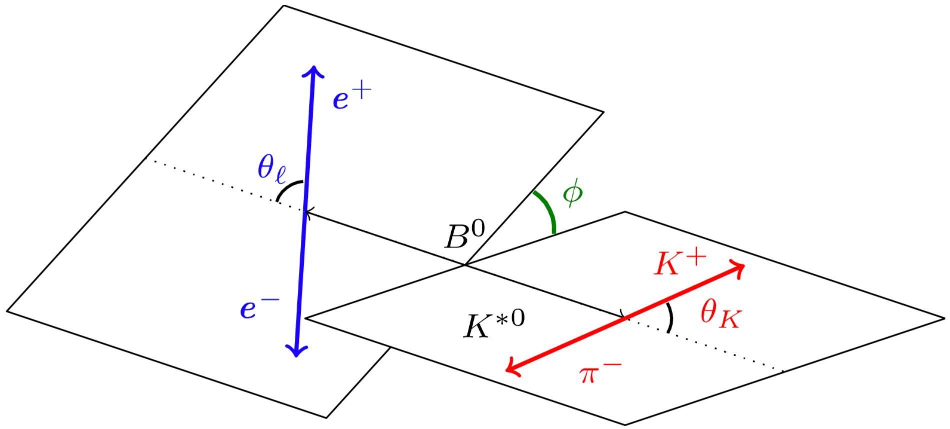
- Select in M(ee) region between 10 MeV and 500 MeV
  Pollution from (axial-)vector currents is negligible in this region

- SM BR is as small as ~ 2×10^{-7} but:
  - Fully charged final state ($K^* \rightarrow K^+\pi^-$)
  - Semileptonic+combinatorial (SL/C) background is phase-space suppressed



530 signal candidates selected with extremely low background

$$\frac{1}{\mathrm{d}(\Gamma+\bar{\Gamma})/\mathrm{d}q^2}\frac{\mathrm{d}^4(\Gamma+\bar{\Gamma})}{\mathrm{d}q^2\,\mathrm{d}\cos\theta_\ell\,\mathrm{d}\cos\theta_K\,\mathrm{d}\tilde{\phi}} = \frac{9}{16\pi}\Big[\tfrac{3}{4}(1-F_\mathrm{L})\sin^2\theta_K + F_\mathrm{L}\cos^2\theta_K$$
$$+\tfrac{1}{4}(1-F_\mathrm{L})\sin^2\theta_K\cos 2\theta_\ell - F_\mathrm{L}\cos^2\theta_K\cos 2\theta_\ell$$
$$+(1-F_\mathrm{L})A_\mathrm{T}^\mathrm{Re}\sin^2\theta_K\cos\theta_\ell$$
$$+\tfrac{1}{2}(1-F_\mathrm{L})A_\mathrm{T}^{(2)}\sin^2\theta_K\sin^2\theta_\ell\cos 2\tilde{\phi}$$
$$+\tfrac{1}{2}(1-F_\mathrm{L})A_\mathrm{T}^\mathrm{Im}\sin^2\theta_K\sin^2\theta_\ell\sin 2\tilde{\phi}\Big]\,.$$



$B^0 \to K^*\gamma$ photon polarisation:

$$A_{\mathrm{R(L)}} \equiv |A_{\mathrm{R(L)}}|e^{i\phi_{\mathrm{R(L)}}},\quad \tan\chi \equiv \left|A_\mathrm{R}/A_\mathrm{L}\right|$$

$$A_\mathrm{T}^{(2)} \simeq \sin(2\chi)\cos(\phi_\mathrm{L}-\phi_\mathrm{R}),$$
$$A_\mathrm{T}^\mathrm{Im} \simeq \sin(2\chi)\sin(\phi_\mathrm{L}-\phi_\mathrm{R}),$$

F_L longitudinal polarisation fraction of the K^{*0}

A_T^{Re} : related to the lepton FB asymmetry

$A_T^{(2)}$: averaged between B^0 and anti-B^0

A_T^{Im} : CP asymmetry

Control channel: $B^0 \to K^{*0} \gamma$

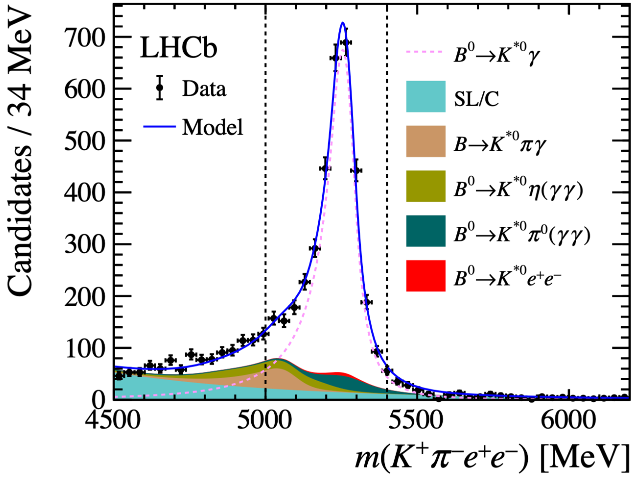
The information on polarisation is lost when the photon converts in the detector material but:

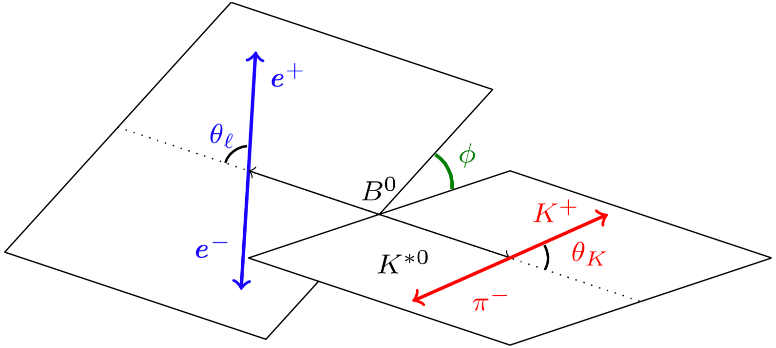
- larger BR
- same final state when the photon converts in the detector
- can be well separated from our signal with M(ee) <10 MeV

What can we check ?

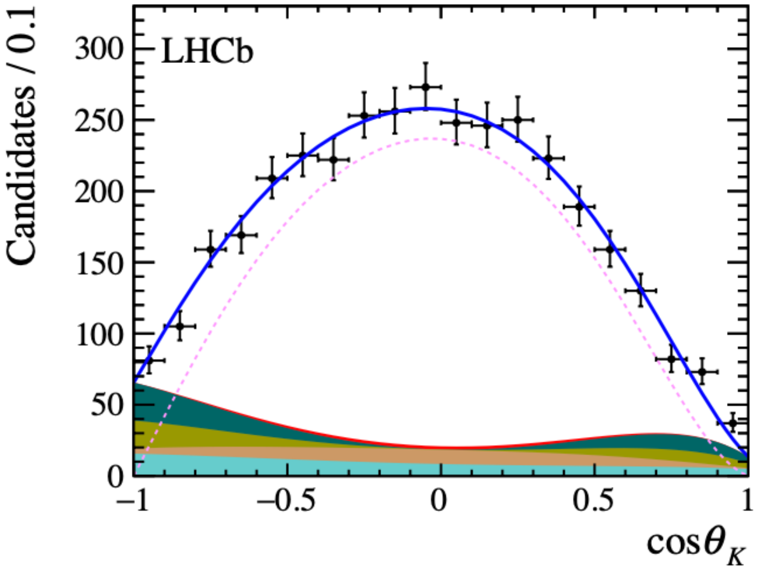
- signal shape and background composition
- signal fit (mass and $\cos\theta_K$)

~ 2950 signal candidates





When $q^2 \rightarrow 0$, only $\cos\theta_K$ is meaningful



$$F_L = 0.0^{+0.7}_{-0.0}\,\%$$

compatible with a completely transverse K^{*0} polarisation (as expected in the presence of a real photon)

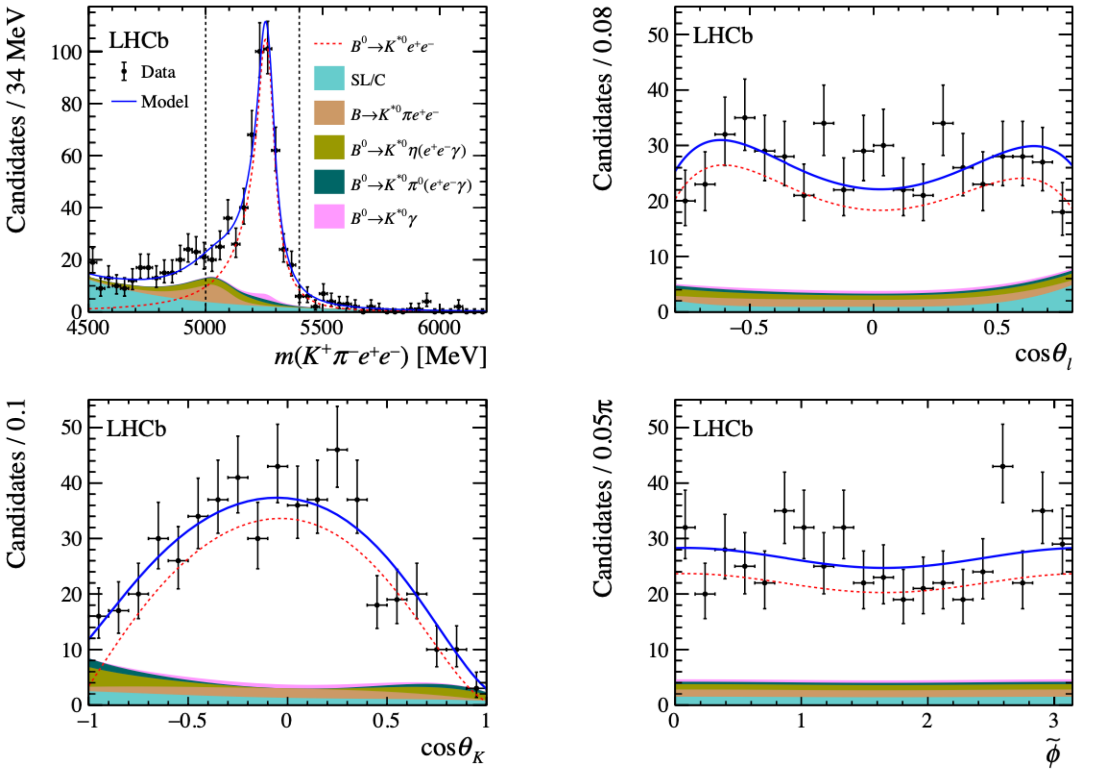
K*ee angular fit

Fit to B mass and angles in reduced mass region

- Semilept+combinatorial (SL/C) modelled using $B \rightarrow K^{*}\mu^{\pm}e^{\mp}$ data

- Other backgrounds from simulation

- Fit procedure tested with pseudo- experiments



IJCLab Irène Joliot-Curie Laboratoire de Physique des 2 Infinis

$$F_{\rm L} = 0.044 \pm 0.026 \pm 0.014,$$
$$A_{\rm T}^{\rm Re} = -0.06 \pm 0.08 \pm 0.02,$$
$$A_{\rm T}^{(2)} = +0.11 \pm 0.10 \pm 0.02,$$
$$A_{\rm T}^{\rm Im} = +0.02 \pm 0.10 \pm 0.01,$$

Statistical uncertainty dominates

Main systematics:

- signal acceptance
- angular background modelling

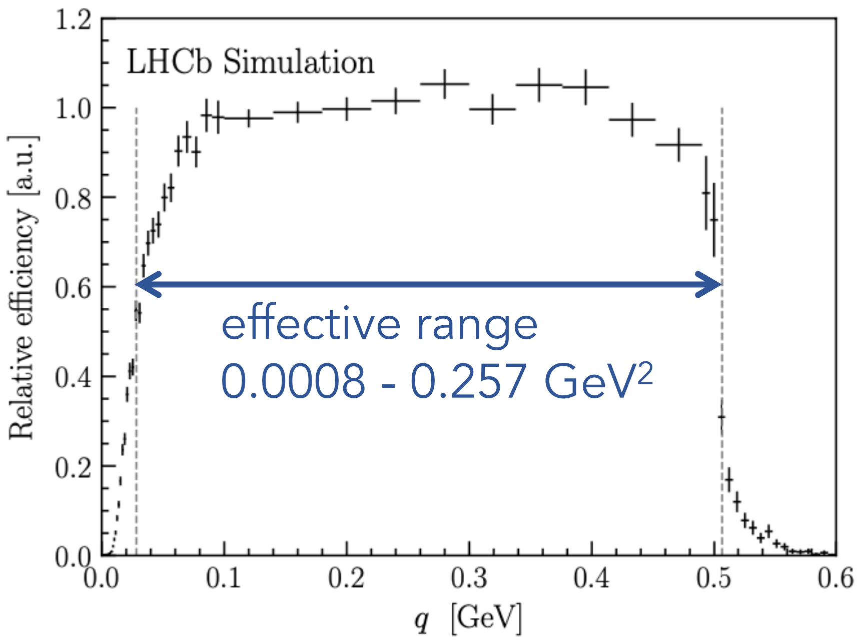
Measurement of the photon polarisation at the 5% level

$$\mathrm{Re}\,(A_{\rm R}/A_{\rm L}) = 0.05 \pm 0.05$$
$$\mathrm{Im}\,(A_{\rm R}/A_{\rm L}) = 0.01 \pm 0.05.$$

Source of systematic	$A_{\rm T}^{(2)}$	$A_{\rm T}^{\rm Im}$	$A_{\rm T}^{\rm Re}$	$F_{\rm L}$
Simulation sample size for acceptance	0.007	0.007	0.007	0.003
Acceptance function modelling	0.004	0.001	0.008	0.001
$B^0 \to K^{*0} e^+ \mu^-$ sample size for SL/C	0.007	0.007	0.007	0.003
SL/C angular modelling	0.012	0.005	0.006	0.005
PR model other than $K_1(1270)$	0.001	0.003	0.002	0.001
η or π^0 angular modelling	< 0.001	< 0.001	0.002	0.010
Corrections to simulation	0.003	0.001	0.003	0.007
Signal mass shape	0.002	0.002	0.004	0.001
Total systematic uncertainty	0.017	0.012	0.015	0.014
Statistical uncertainty	0.103	0.102	0.077	0.026

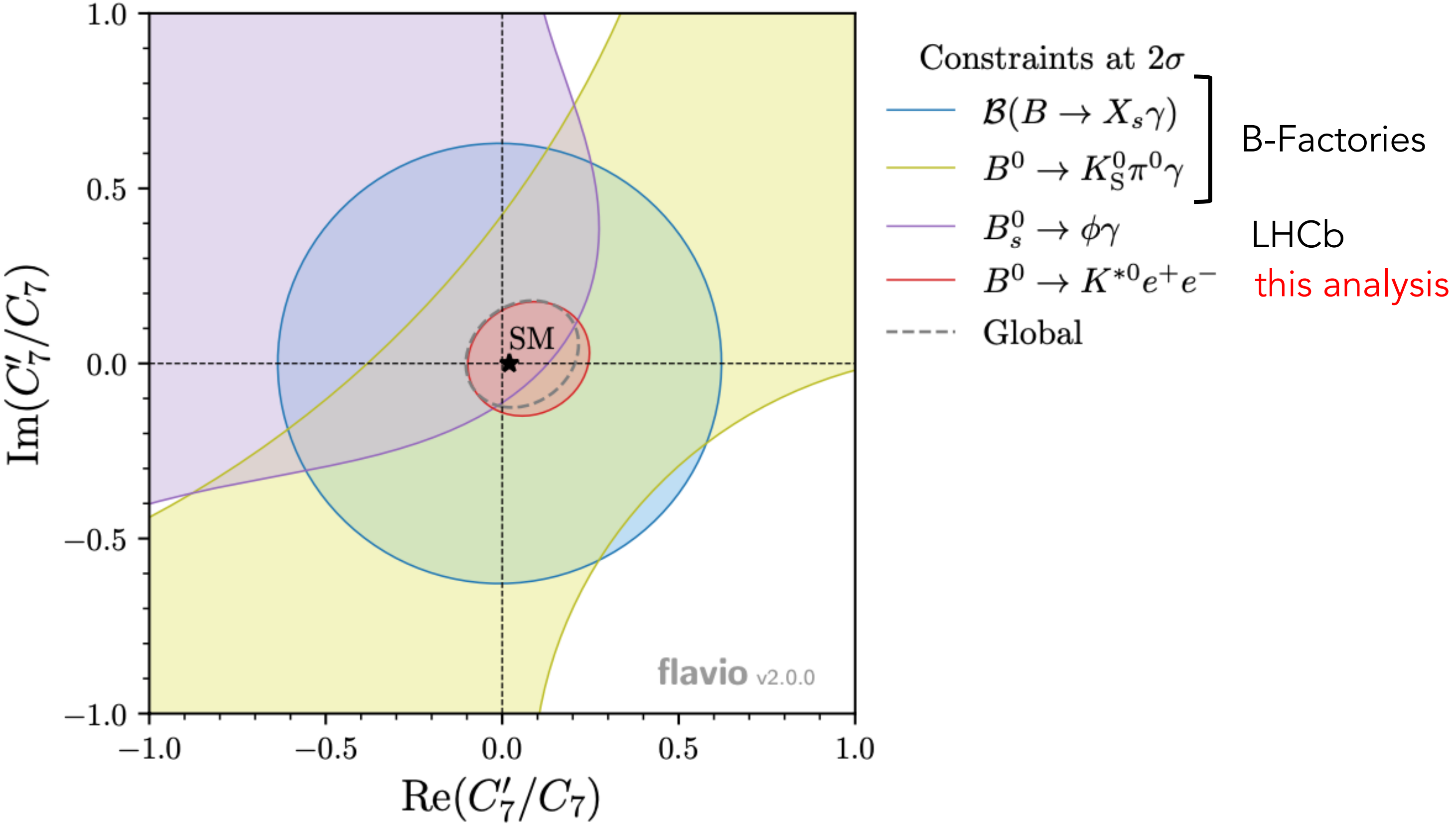
Comparison with predictions

Selection : $0.0001<q^2< 0.25$ GeV^2



$$
\begin{aligned}
F_{\rm L}(\rm SM) &= \quad 0.051 \pm 0.013, \\
A_{\rm T}^{\rm Re}(\rm SM) &= -0.0001 \pm 0.0004, \\
A_{\rm T}^{(2)}(\rm SM) &= \quad 0.033 \pm 0.020, \\
A_{\rm T}^{\rm Im}(\rm SM) &= -0.00012 \pm 0.00034.
\end{aligned}
$$

Irène Joliot-Curie
Laboratoire de Physique des 2 Infinis



C_7 fixed to SM value

Summary

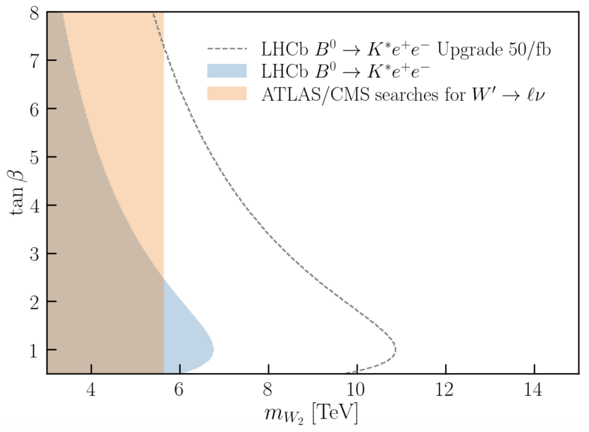
World-best masurement of photon polarisation in b→sγ transitions

Method very different from B-Factories

Statistically limited measurement
⇒will keep improving with more luminosity (upgrade)

Using the formalism of 1305.3173

Seq-LR SSM



IJCLab Irène Joliot-Curie Laboratoire de Physique des 2 Infinis