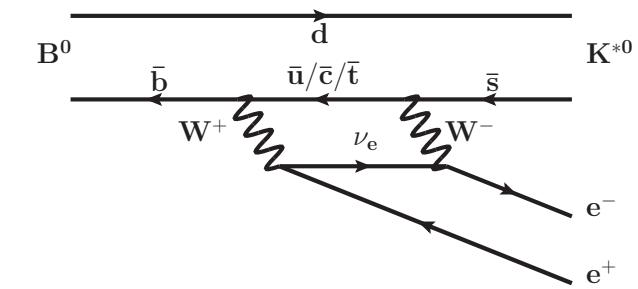
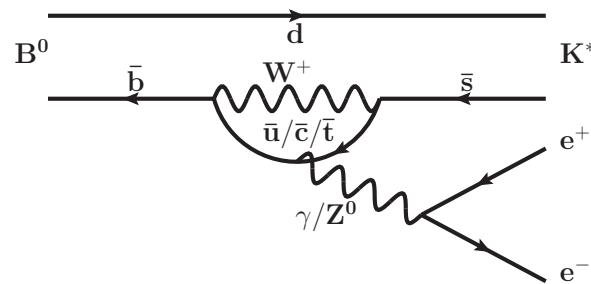
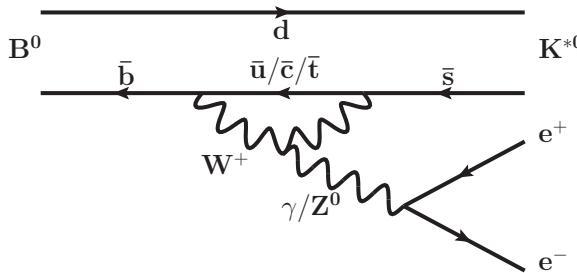




Eli Ben-Haim, Samuel Coquereau, Jibo He, Jacques Lefrancois, Michele Nicol, Francesco Polci, Claire Prouve, Marie-Helene Schune, Justine Serrano

- Introduction
- $B \rightarrow K^* \mu \mu$ with emphasis on the french contributions
- $B \rightarrow K^* ee$: motivation and current status

Introduction



Interferences between all these diagrams: a large number of observables

System described by

- $q^2 = M^2(\ell\ell)$
- 3 angles

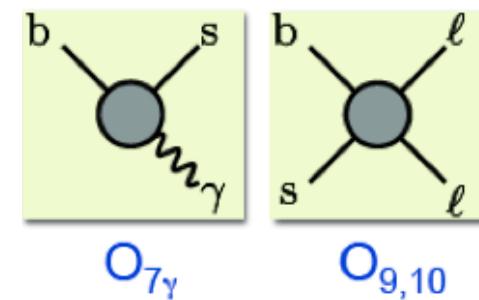
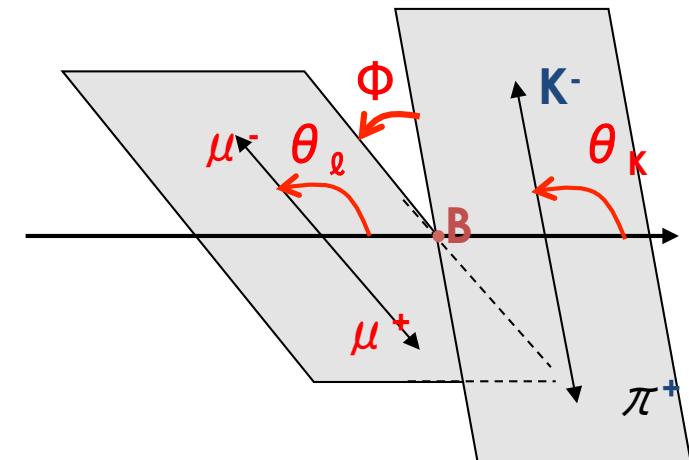
Model independent approach using OPE:

Right handed part
(suppressed in SM)

$$H_{\text{eff}} = -\frac{4G_F}{\sqrt{2}} V_{tb} V_{ts}^* \sum_{i=7,9,10} \left(C_i(\mu) \times O_i(\mu) + C'_i(\mu) \times O'_i(\mu) \right)$$

C_i : short distance
Wilson coefficient
(pert.)

O_i : long distance
operator (non-pert.)



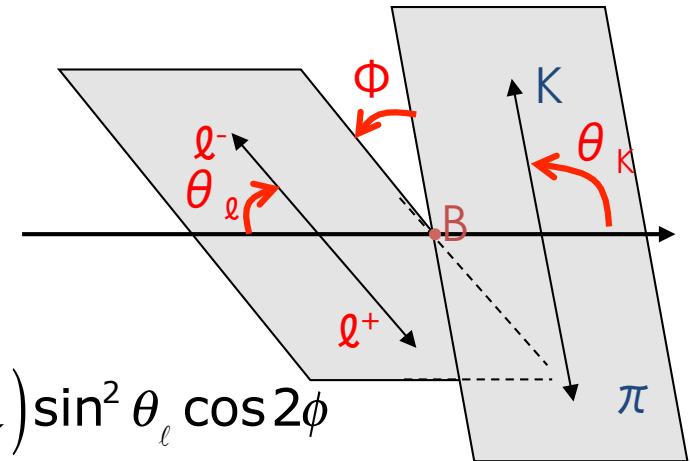
Formulae

Kruger and Matias hep-ph 0502060

$$\frac{d\Gamma}{dq^2 d\cos\theta_K d\cos\theta_\ell d\phi} = \frac{9}{32\pi} I(q^2, \cos\theta_K, \cos\theta_\ell, \phi)$$

The $C^{(\prime)}_{7..10}$ are encoded in the $I_{i=1..9}$

$$I = I_1(q^2, \cos\theta_K) + I_2(q^2, \cos\theta_K) \cos 2\theta_\ell + I_3(q^2, \cos\theta_K) \sin^2 \theta_\ell \cos 2\phi \\ + I_4(q^2, \cos\theta_K) \sin 2\theta_\ell \cos\phi + I_5(q^2, \cos\theta_K) \sin\theta_\ell \cos\phi + \\ I_6(q^2, \cos\theta_K) \cos\theta_\ell + I_7(q^2, \cos\theta_K) \sin\theta_\ell \sin\phi + \\ I_8(q^2, \cos\theta_K) \sin 2\theta_\ell \sin\phi + I_9(q^2, \cos\theta_K) \sin^2 \theta_\ell \sin 2\phi$$



Φ transformation:

if $\Phi < 0$ then $\Phi = \Phi + \pi$: keeps $\cos(2\Phi)$ and $\sin(2\Phi)$ effects cancels $\cos(\Phi)$ and $\sin(\Phi)$ effects (including acceptance effects) !



$$I = I_1(q^2, \cos\theta_K) + I_2(q^2, \cos\theta_K) \cos 2\theta_\ell + I_3(q^2, \cos\theta_K) \sin^2 \theta_\ell \cos 2\phi \\ I_6(q^2, \cos\theta_K) \cos\theta_\ell + I_9(q^2, \cos\theta_K) \sin^2 \theta_\ell \sin 2\phi$$

$$\begin{aligned}
& \frac{d\Gamma}{dq^2 d\cos\theta_K d\cos\theta_\ell d\phi} \propto \\
& F_L \cos^2 \theta_K + \frac{3}{4} (1 - F_L) (1 - \cos^2 \theta_K) + (2 \cos^2 \theta_\ell - 1) \left(\frac{1}{4} (1 - F_L) (1 - \cos^2 \theta_K) - F_L \cos^2 \theta_K \right) \\
& + \frac{1}{2} (1 - F_L) A_T^2 (1 - \cos^2 \theta_K) (1 - \cos^2 \theta_\ell) \cos 2\phi + \frac{4}{3} A_{FB} (1 - \cos^2 \theta_K) \cos \theta_\ell + \\
& \frac{1}{2} (1 - F_L) A_T^{\text{Im}} (1 - \cos^2 \theta_K) (1 - \cos^2 \theta_\ell) \sin 2\phi
\end{aligned}$$

Four parameters to fit (F_L , A_{FB} , A_T^2 and A_T^{Im}) in bins of q^2

F_L is the fraction of longitudinal polarization

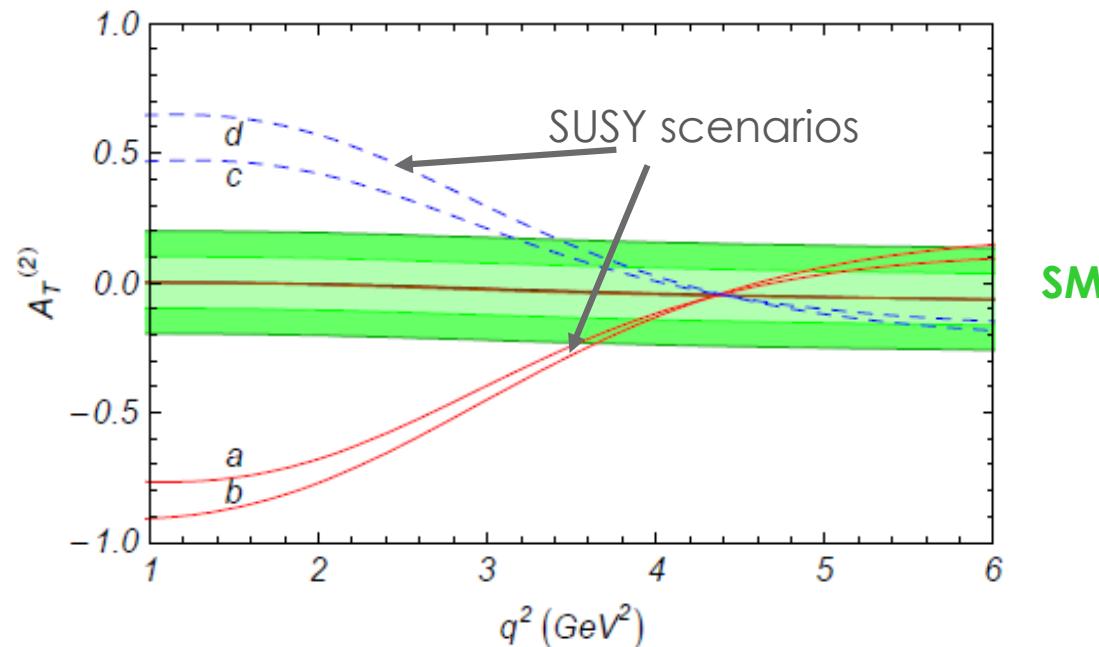
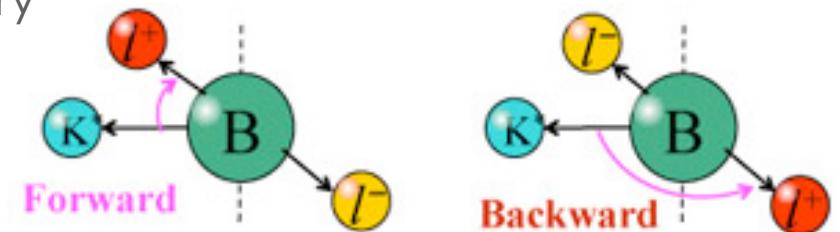
$$F_L = \frac{|A_0|^2}{|A_0|^2 + |A_\perp|^2 + |A_{||}|^2}$$

A_{FB} is the lepton Forward Backward asymmetry

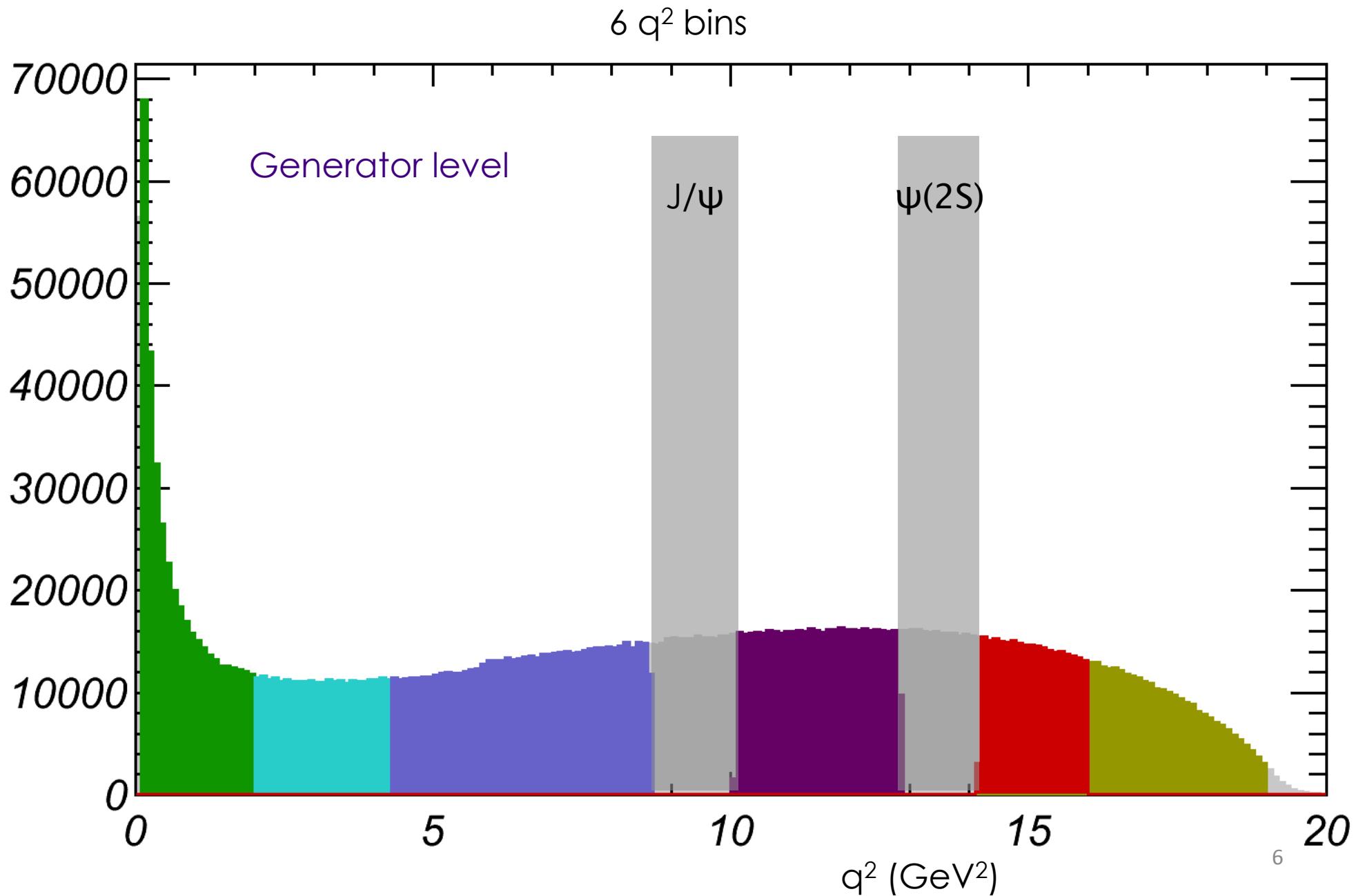
The q^2 value at which $A_{FB}=0$ is a sensitive probe to New Physics

$$A_T^{(2)} = \frac{|A_\perp|^2 - |A_{||}|^2}{|A_\perp|^2 + |A_{||}|^2}$$

$$A_T^{\text{Im}} = \frac{\text{Im}(A_{||L}^* A_{\perp L})}{|A_\perp|^2 + |A_{||}|^2}$$

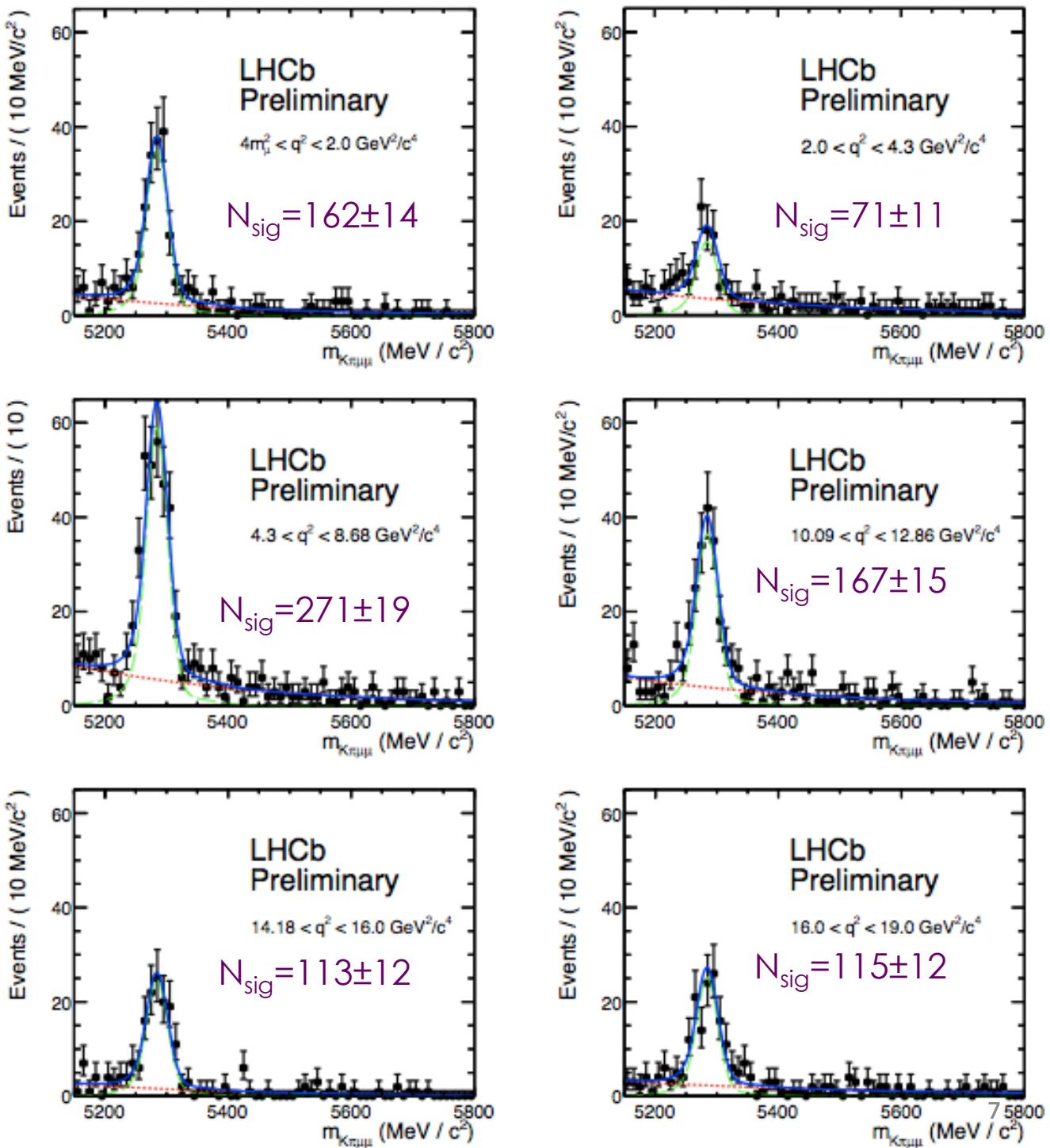


$B \rightarrow K^* \mu\mu$ analysis



B mass for the 6 q^2 bins

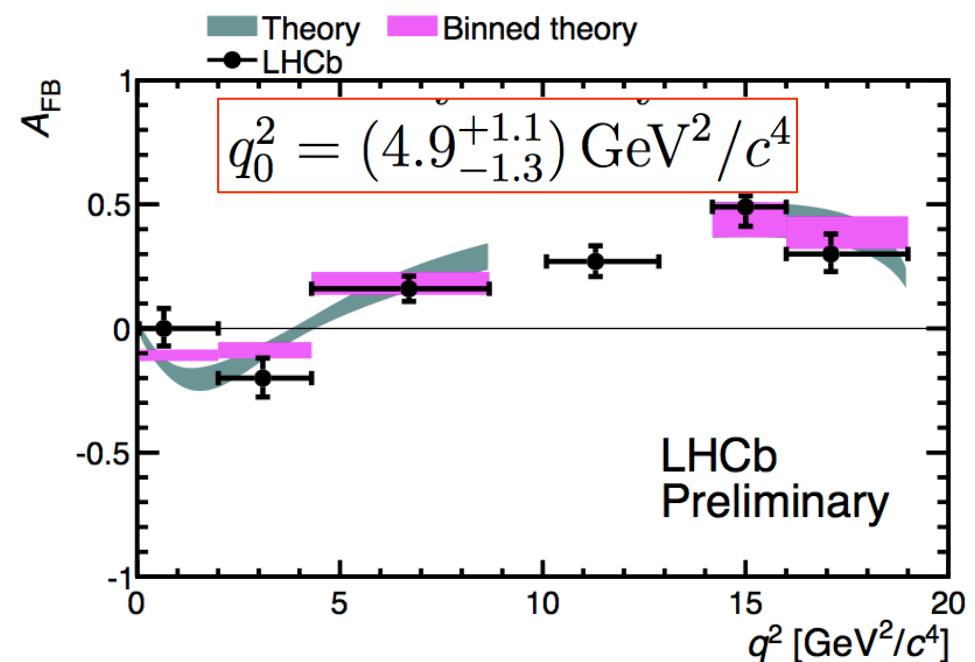
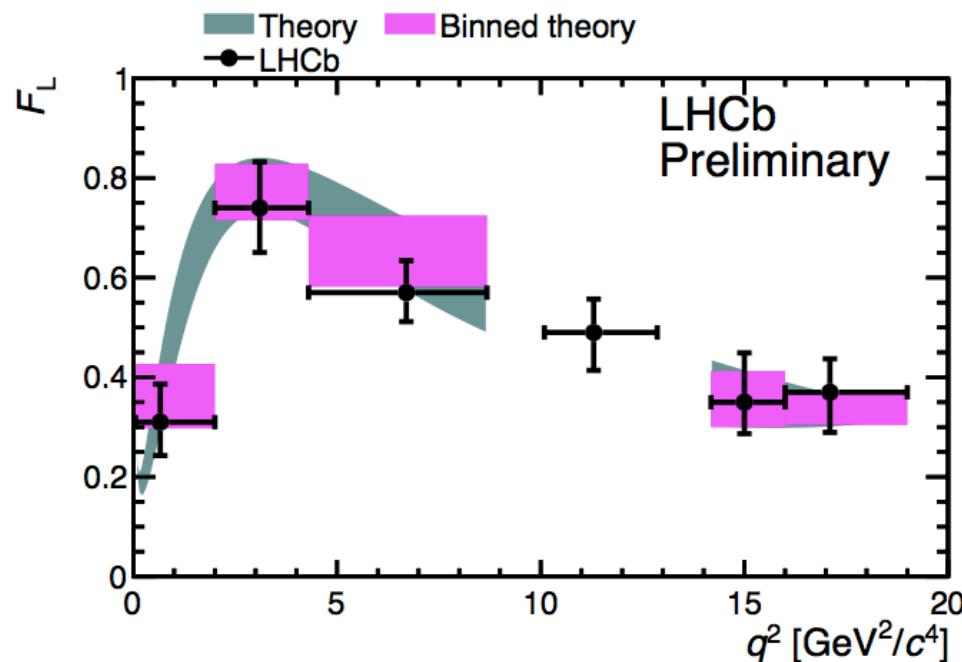
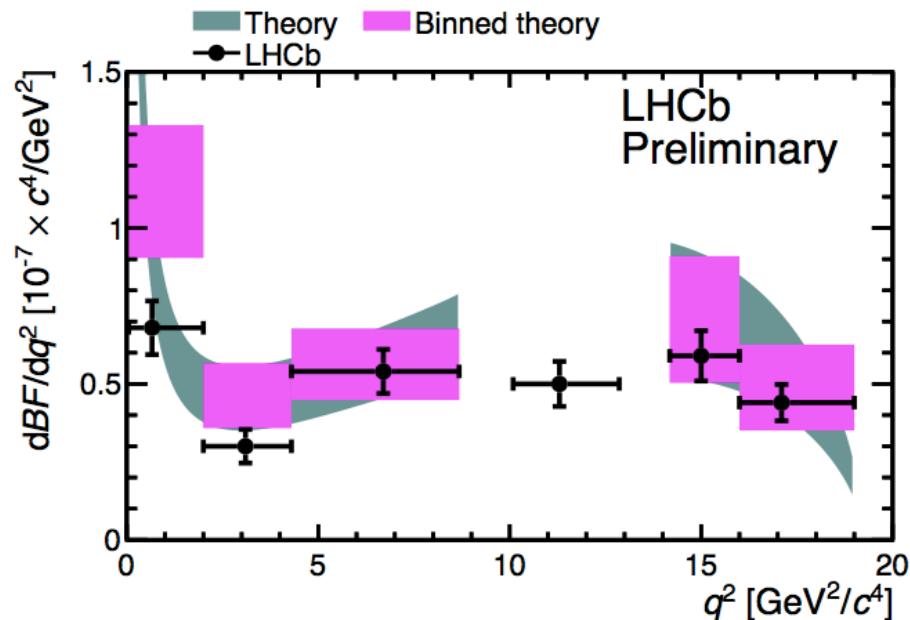
2011 data (1 fb^{-1})

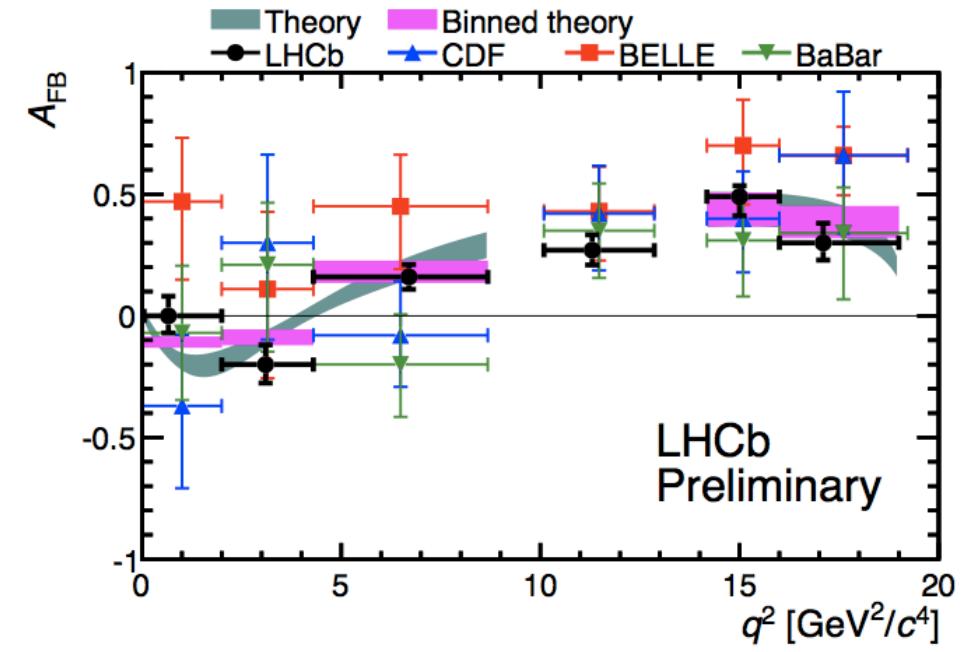
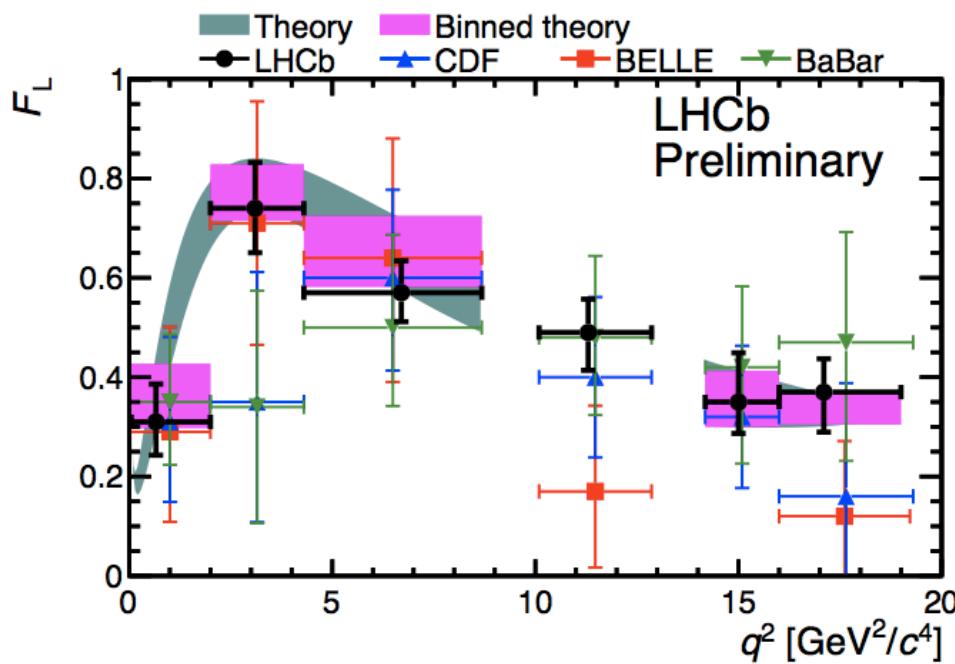
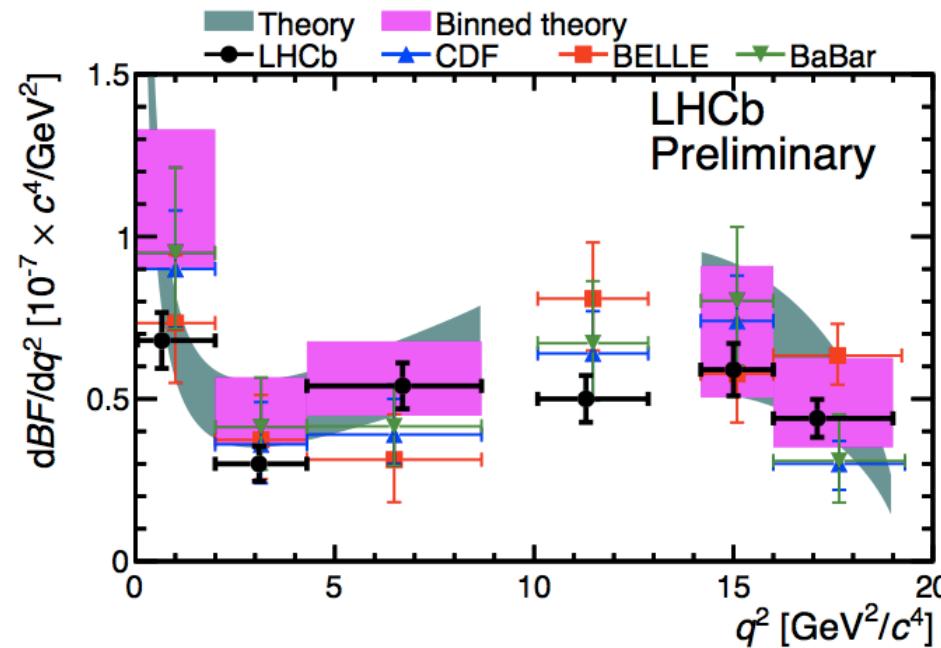


LHCb-CONF-2012-008

The differential BF has large theoretical uncertainty
 ⇒ fit of the angular variables

Theory predictions
 from C. Bobeth et al
 arXiv:11105.0376

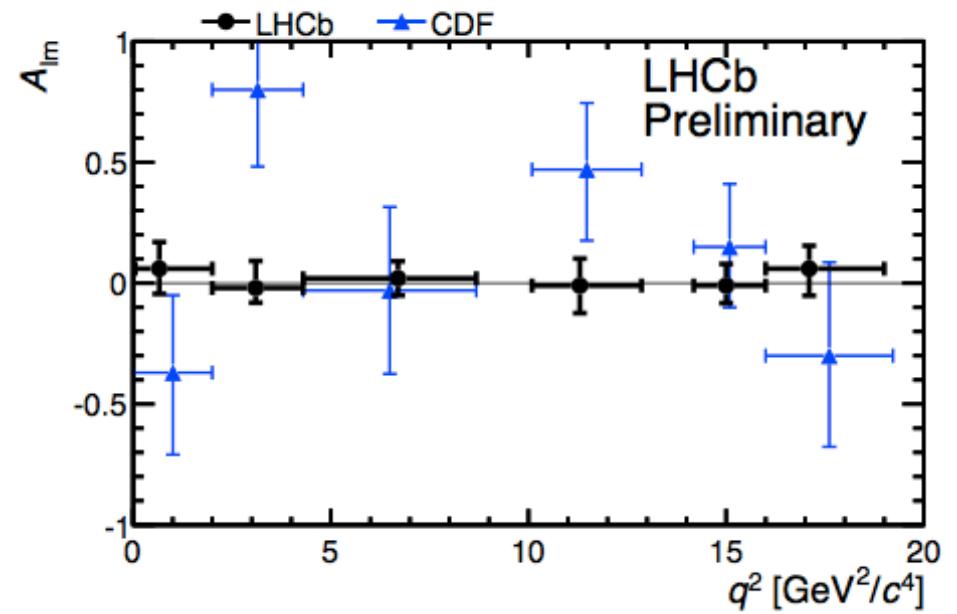
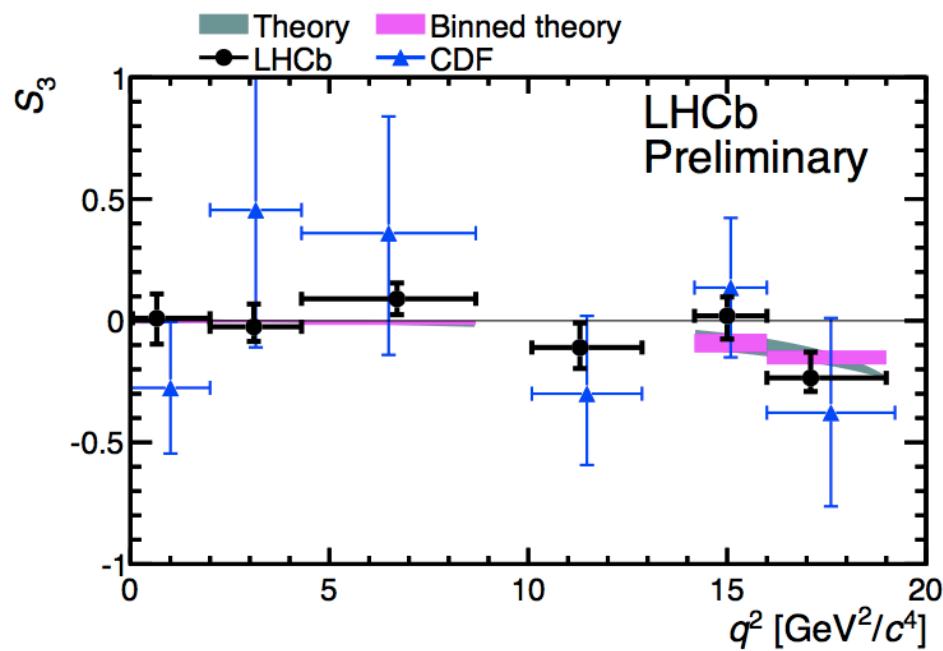




Improved precision compared to other experiments
Good agreement with the SM ...

Preliminary result from LHCb : S_3 and A_{Im}

$$\frac{d\Gamma}{d \cos\phi} \propto \frac{1}{2} \left(1 - F_L\right) A_T^2 \cos 2\phi + \frac{1}{2} \left(1 - F_L\right) A_T^{\text{Im}} = S_3 \cos 2\phi + A_{\text{Im}} \sin 2\phi$$



CDF Phys.Rev.Lett.108(2012)081807

Partial summary

- results in agreement with the SM
- uncertainties improved by a factor > 2 wrt other experiments

But :

- also need to provide the results for theoretically cleaner parameters
- several delicate points have to be taken into account (and were not in previous analyses)
- LHCb paper to appear within few weeks

Effect of an S-wave under the K^{*0} peak

All the angular distributions shown before assume that the ($K\pi$) system is a $K^{*0}(892)$ spin-1 meson

With an S-wave:

$$(1 - F_S) \frac{1}{d\Gamma/dq^2} \frac{d\Gamma}{dq^2 d\cos\theta_K d\cos\theta_\ell d\phi} + \frac{9}{16\pi} \left[\frac{2}{3} F_S (1 - \cos^2 \theta_\ell) + \frac{4}{3} A_S \cos\theta_K (1 - \cos^2 \theta_\ell) \right]$$

↑ ↑

Squared amplitude of the S-wave interference between the S-wave and the longitudinal amplitude of the K^{*0}

Two additional parameters, not enough data to perform the fit.
Even if F_S is small A_S can be non-negligible.

Split the data sample in two regions: $m(K\pi) < M_{K^{*0}}$ and $m(K\pi) > M_{K^{*0}}$ to exploit the $K^{*0}(892)$ BW shift around the pole and extract A_S^+ and A_S^-

F_S can be expressed as a function of A_S^+ and A_S^-

F_S compatible with 0

The first q^2 bin

the differential decay rate assumes that $q^2 \gg 4m_\mu^2$

⇒ use only the range $0.1 < q^2 < 2 \text{ GeV}^2$ not $4m_\mu^2 < q^2 < 2 \text{ GeV}^2$

⇒ additional q^2 dependence in the bin $0.1 < q^2 < 2 \text{ GeV}^2$ proportional to

$$\frac{1 - 4m_\mu^2/q^2}{1 + 2m_\mu^2/q^2} \quad \text{or} \quad \sqrt{\frac{1 - 4m_\mu^2/q^2}{1 + 2m_\mu^2/q^2}}$$

When $q^2 \rightarrow 4m_\mu^2$ dilution of the impact of the observables on the angular distribution

Omitting this dependence in the Likelihood : discrepancy between the experimental observables and the theoretical ones.

Correction factors of the order of 10%- 20% (on the central value and on the uncertainty)

The first q^2 bin is particularly interesting since in this region the diagrams with the photon dominate: clean test of the SM :

the photon is left-handed in $b \rightarrow s\gamma$ transitions

$$A_T^2 = -2 \operatorname{Re} \left(\frac{A_R^* A_L}{|A_R|^2 + |A_L|^2} \right) \underset{\uparrow}{\approx} -2 \frac{A_R}{A_L}$$

If A_R/A_L small and real

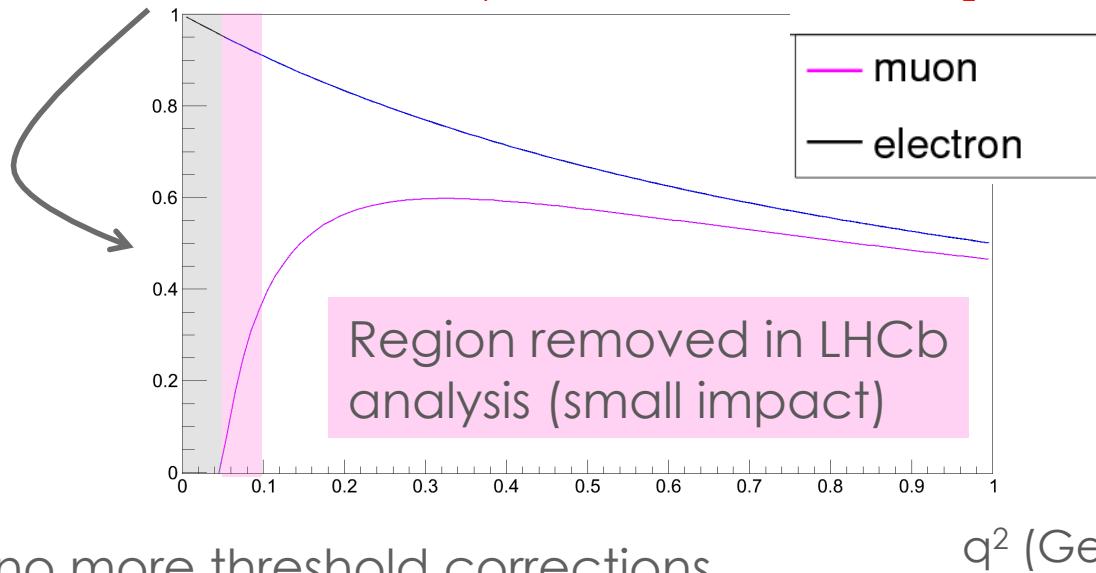
$$A_T^2(q^2 = 0) = \frac{2 \operatorname{Re} [C_7^{\text{eff}} C_7^{\text{'eff}*}]}{|C_7^{\text{eff}}|^2 + |C_7^{\text{'eff}}|^2}$$

⇒ go for the smallest q^2

B \rightarrow K*ee analysis

Why ?

- access to much lower q^2 values:
 - more events (photon pole)
 - larger sensitivity to A_T^2 due to the lower F_L value

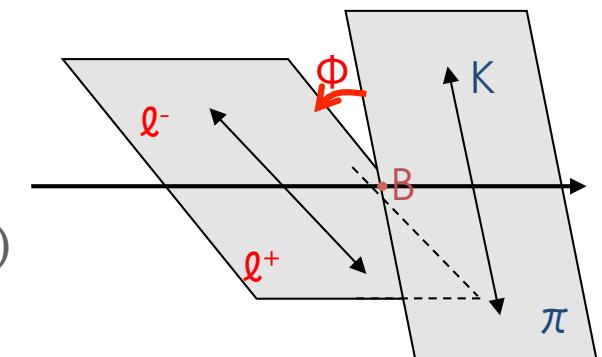
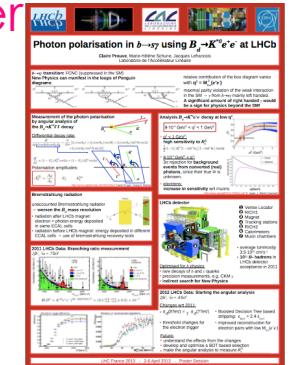


- no more threshold corrections

Which q^2 range ?

- $M(ee) > 30$ MeV
 - (below the ϕ angle cannot be measured precisely enough because of multiple scattering)
 - $B \rightarrow K^*\gamma$ background
- $M(ee) < 1000$ MeV: above no sensitivity to A_T^2 due to the high F_L value (~ 0.8)

Claire Prouvé's poster

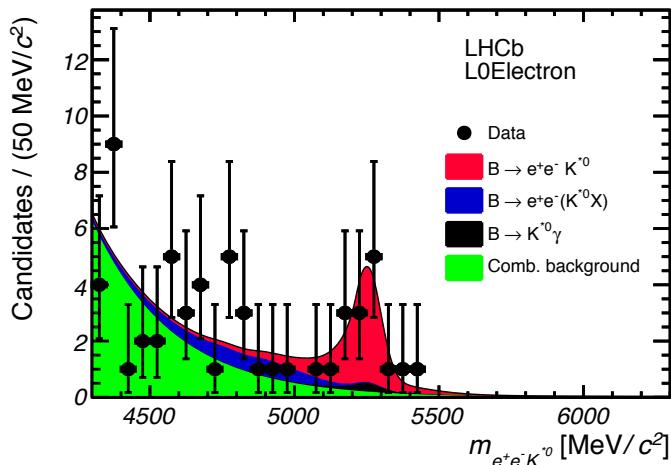


$$\Rightarrow 0.009 < q^2 < 1 \text{ GeV}^2$$

But

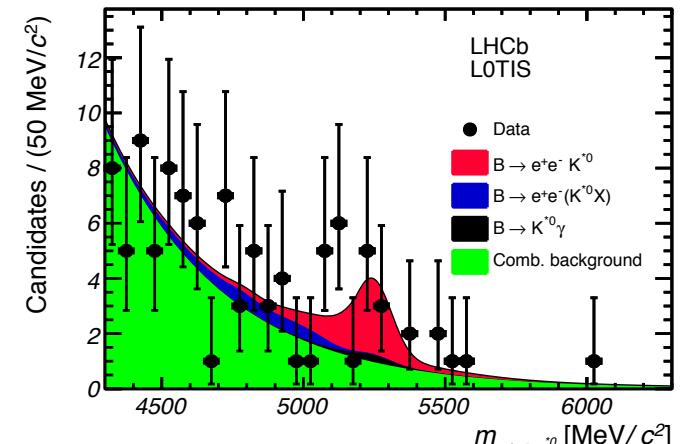
- triggering is more difficult: loss of efficiency
- worse momentum resolution because of bremsstrahlung

2011 data (1 fb^{-1}): BR measurement wrt $B \rightarrow J/\Psi(\rightarrow ee) K^{*0}$



$$N_{sig} = 15.0^{+5.1}_{-4.5}$$

2 trigger categories



$$N_{sig} = 14.1^{+7.0}_{-6.3}$$

Significance (stat+syst): 4.6σ

$$B(B^0 \rightarrow K^{*0} e^+ e^-)^{30-1000 \text{ MeV}/c^2} = (3.1^{+0.9 +0.2}_{-0.8 -0.3} \pm 0.2) \times 10^{-7}$$

in good agreement with the theoretical prediction: $(2.43^{+0.66}_{-0.47}) \times 10^{-7}$

Summary and future plans

2011-2012 data sample: 3 fb^{-1} , we have analyzed only 1 fb^{-1}

- full angular fit for $B \rightarrow K^* \mu \mu$
⇒ directly constraint the Wilson coefficients ?
- improve the selection (use of isolation criteria on muon tracks)
- optimize the selection as a function of q^2 ?
- enough data to measure the S-wave contribution ?
- perform an angular fit for $B \rightarrow K^* ee$
⇒ revisit the selection

And after ?

- Upgrade

Zero crossing
point of A_{FB}



$B \rightarrow K^* \mu \mu$	$\sigma (A_T^2)$	$\sigma (q_0^2)$
Now	0.5	$\sim 25\%$
After the upgrade	0.04	2 %

"Imagine if Fitch and Cronin had stopped at the 1% level, how much physics would have been missed"

A. Soni at the Opening meeting for the Super-KeKB proto-collaboration (2008)

backup slides

