$B^0 \to K^{*0}e^+e^-$ angular analysis at low q^2 at LHCb

Fabrice Desse

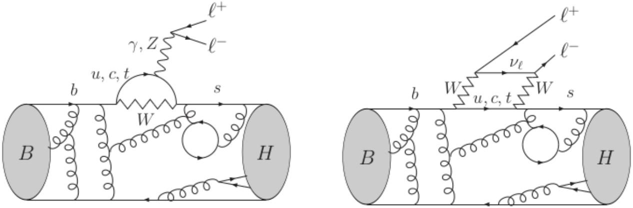
Laboratoire de l'Accelerateur Lineaire / University of Paris Sud-Saclay
Orsay, France

Motivations to study $b \to sll$

A probe for New Physics (NP)

$b \to sll$ transitions are Flavour Changing Neutral Currents (FCNC) forbidden at tree-level in the Standard Model (SM):

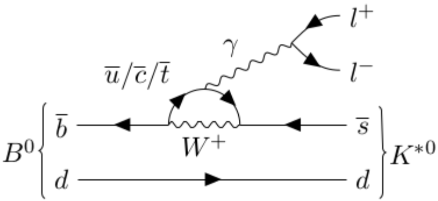
- Sensitive to NP at loop level
- Can probe NP at much larger scales than direct searches



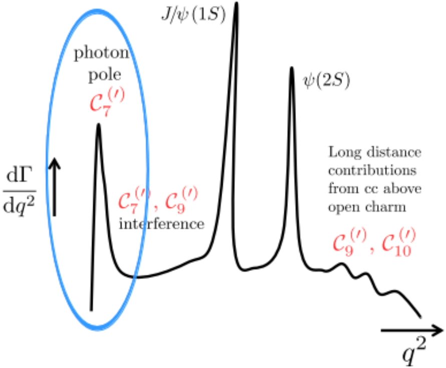
Parametrize NP contributions in a model independant way using effective field theory:

$$\mathcal{H}_{eff} \propto V_{tb} V_{ts}^{*} \sum_{i} \left(\mathcal{C}_i \mathcal{O}_i + \mathcal{C}_i' \mathcal{O}_i' \right)$$

Motivations to study $B^0 \to K^{*0} l^+ l^-$ at low q^2



- With $e^{\pm}$ can go much lower in q^2 than with $\mu^{\pm}$
- Sensitive $\sim$ only to $\mathcal{C}_7^{(\prime)}$

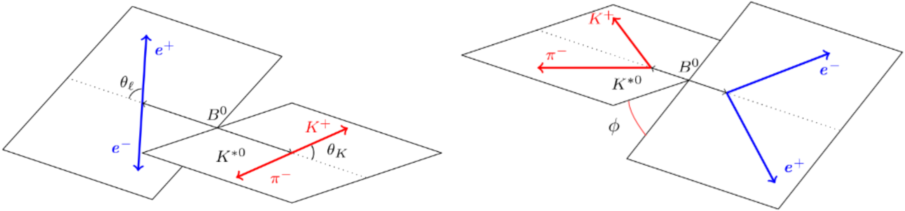


Putting constraints on $\mathcal{C}_7^{(\prime)}$

by measuring the angular distribution of $B^0 \to K^{*0} e^+ e^-$ at low q^2

$$d^4\Gamma\left(B^0 \to K^{*0} e^+ e^-\right) = [\text{Probability density}] \times [d\text{Volume}] \quad ,$$

$$d\text{Volume} = dq^2 \times d\Omega = dq^2 \times d(\cos\theta_l)d(\cos\theta_k)d\phi$$



$$[\text{Probability density}] = \sum_i [\text{Physics}_i] \times [\text{Kinematics}_i]$$

$$= \sum_i [\mathcal{I}_i(q^2, \underline{\textbf{Wilson coefs}}, \text{form factors})] \times [f(\cos\theta_l, \cos\theta_k, \phi)]$$

Putting constraints on $\mathcal{C}_7^{(\prime)}$

The measurement

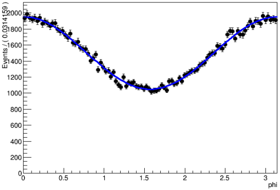
We fit simultaneously the $\cos\theta_l$, $\cos\theta_k$ and ϕ distributions.

$$\left\langle \frac{d^4\Gamma}{dq^2 d(\cos\theta_l) d(\cos\theta_k) d\phi} \right\rangle_{CP} = f(\mathcal{I}_i, \cos\theta_l, \cos\theta_k, \phi)$$

$$= f(F_L(\mathcal{I}_i), A_T^{(2)}(\mathcal{I}_i), A_T^{Im}(\mathcal{I}_i), A_T^{Re}(\mathcal{I}_i), \cos\theta_l, \cos\theta_k, \phi)$$

What we are trying to determine

Our physical observables



Example: one of the 3 angular fits (here to ϕ). Toy of $B^0 \to K^{*0} e^+ e^-$ NP-like pseudo data

- Fit the data to extract a value for F_L, $A_T^{(2)}$, A_T^{Im}, A_T^{Re}
- Constrain $C_7^{(\prime)}$: e.g. $A_T^{(2)}(q^2 \to 0) = 2\frac{\mathcal{R}e\left(\mathcal{C}_7 \mathcal{C}_7'^{*}\right)}{|\mathcal{C}_7|^2 + |\mathcal{C}_7'|^2}$

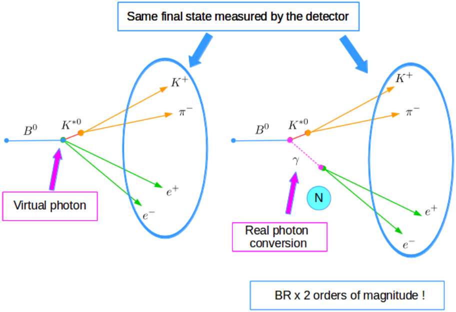
Lower q^2 boundary

$$A_T^{(2)} = f(\mathcal{C}_7^{(\prime)}) \left(1 + \alpha \frac{\mathcal{C}_9}{\mathcal{C}_7}\right) \frac{1}{1 + \alpha g(\mathcal{C}_{7,9}^{(\prime)}) + \alpha^2 h(\mathcal{C}_{7,9,10}^{(\prime)})} \;, \quad \alpha = 0.0226 q^2$$

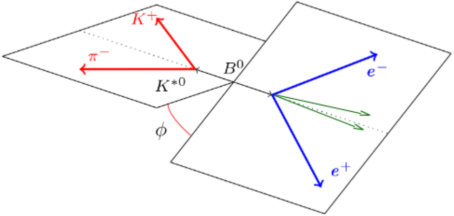
[arxiv:hep-ph/0502060]

So in principle, go down to threshold $m(e^+e^-) = 2m_e$.
But, experimental limitations:

1) $B^0 \to K^{*0}\gamma(\to e^+e^-)$ conversions



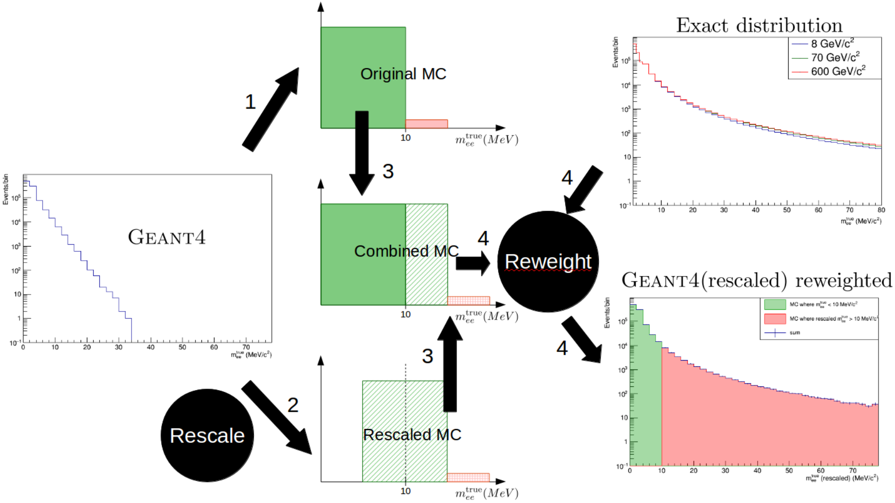
2) Lower $q^2 \Rightarrow$ lower dielectron angle



Reconstruct dielectron plane (i.e. ϕ) is easy hard

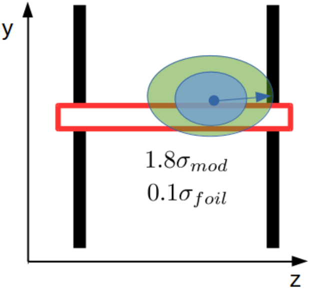
Reweighting the MC $B^0 \to K^{*0}\gamma(\to e^+e^-)$ generated by Geant4

Due to an oversimplification of the angular distribution of converted photons

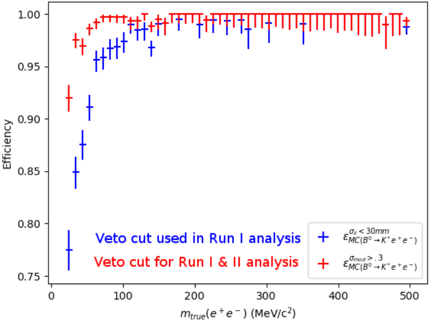


Vetoing converted photons

Conversions happen in the material of the VELO: veto pairs compatible with originating from the material

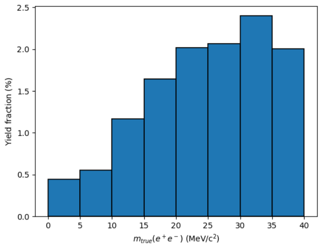


Signal efficiency, comparison with previous cut used in Run I analysis



Going lower in q^2

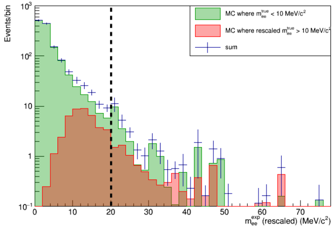
Expected additional signal yield versus additional converted photons contamination



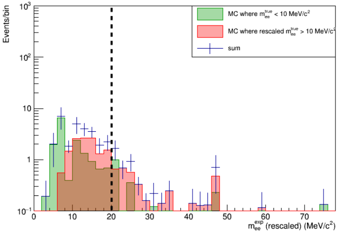
Run I $m(e^+e^-)$ range $= [20, 1000]$ MeV/c^2:

- Add bin [15,20] ? +1.5 % signal, but 80 % contamination
- Remove bin [20,25] ? -2 % signal, contamination only 20 %

So 20 MeV/c^2 is the optimal lower limit.



No veto σ_{mod}



Veto $\sigma_{\mathrm{mod}} > 0.3$

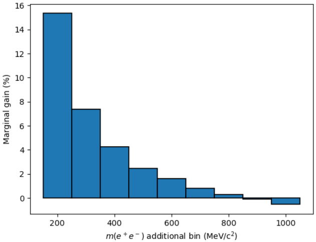
Upper q^2 limit

Sensitivity to $A_T^{(2)}$

The fit to ϕ is the one which constrains the most $A_T^{(2)}$

$$\text{In a given } q^2 \text{ bin: } \left\langle \frac{d\Gamma}{d\phi} \right\rangle_{CP, q^2, \cos\theta_l, \cos\theta_k} \propto (1 - < F_L >_{q^2}) < A_T^{(2)} >_{q^2}$$

But F_L increases with $q^2 \Rightarrow$ decreases sensitivity to $A_T^{(2)}$.



Marginal gain on statistical error of $A_T^{(2)}$ wrt to previous bin

$$N_{eff} = N(1 - < F_L >_{q^2})^2 \ ,$$

$$\nearrow \text{upper } q^2 \Rightarrow N \nearrow (1 - < F_L >_{q^2} \nearrow)^2$$

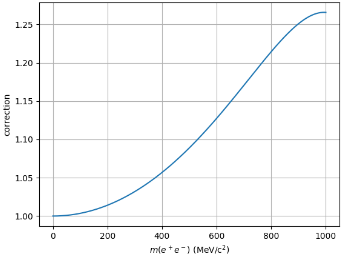
- If low limit is 20 MeV/c^2, up to $\sim$ 850 MeV/c^2 there is a gain
- To constrain $\mathcal{C}_7^{(\prime)}$, chose $m(e^+e^-) < 850$ MeV/c^2

Upper q^2 limit

Sensitivity to $\mathcal{C}_7^{(')}$

$$A_T^{(2)} = f(\mathcal{C}_7^{(')}) \left(1 + \alpha \frac{\mathcal{C}_9}{\mathcal{C}_7}\right) \frac{1}{1 + \alpha g(\mathcal{C}_{7,9}^{(')}) + \alpha^2 h(\mathcal{C}_{7,9,10}^{(')})} \quad , \quad \alpha = 0.0226 q^2$$

$$A_T^{(2)} = f(\mathcal{C}_7^{(')}) \times Corr(q^2, \mathcal{C}_{7,9,10}^{(')})$$



$Corr(q^2, \mathcal{C}_{7,9,10}^{(')})$ in the SM as a function of $< m(e^+e^-) >$

- To get $Corr(q^2, \mathcal{C}_{7,9,10}^{(')}) < 2\%$, chose $m(e^+e^-) < 500$ MeV/c^2
- Safely away from wide ρ^0 resonance (770 MeV/c^2, width 150 MeV/c^2)

Conclusion (1/2)

- Why this analysis ?
  - $B^0 \to K^{*0} e^+ e^-$ is sensitive to NP at loop level
  - Can put constraints on $\mathcal{C}_7^{(\prime)}$ at very low q^2 (allowed by $e^\pm$, not by $\mu^\pm$)
  - ... by measuring the angular distribution.
- Which q^2 bin ?
  - "Pure $\mathcal{C}_7^{(\prime)}$" bin:
    - Lower limit = 20 MeV/c^2, driven by converted photons contamination
    - Higher limit = 500 MeV/c^2, maximize sensitivity, away from ρ^0
  - "$\mathcal{C}_7^{(\prime)}, \mathcal{C}_9^{(\prime)}$ interference" bin $[500, 1050]$ MeV/c^2

bins (MeV/c^2)	$N_{\rm data}^{\rm Run\ I\ \&\ II}$ lower bin (no 2018)	$N_{\rm data}^{\rm Run\ I\ \&\ II}$ upper bin (no 2018)
20 - 500 / 500 - 1050	545 (389)	205 (142)

Table: Rough estimate of expected yields

Expected sensitivity Run I & II (no 2018):

$\epsilon(A_T^{(2)}) \sim 10(12)\%$ ϵ photon polarization $\sim 5(6)\%$

Conclusion (2/2)

- Selection (incl. MVA to remove combinatorial background) ✓
- Specific background studies
  - $B^0 \to K^{*0}\gamma(\to e^+e^-)$ ✓
  - Currently studying $B^0 \to K^{*0}\eta/\pi^0(\to e^+e^-\gamma)$
- Determination of the angular acceptance
- Angular modelling of backgrounds
- Fit validation and systematics