Why is it interesting to study $B^0 \to K^{*0} e^+ e^-$?

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Workshop: "Flavor of New Physics in b $\to$ s transitions"

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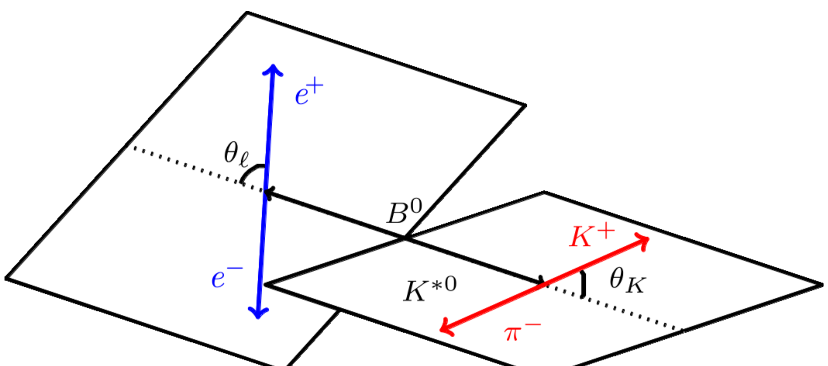
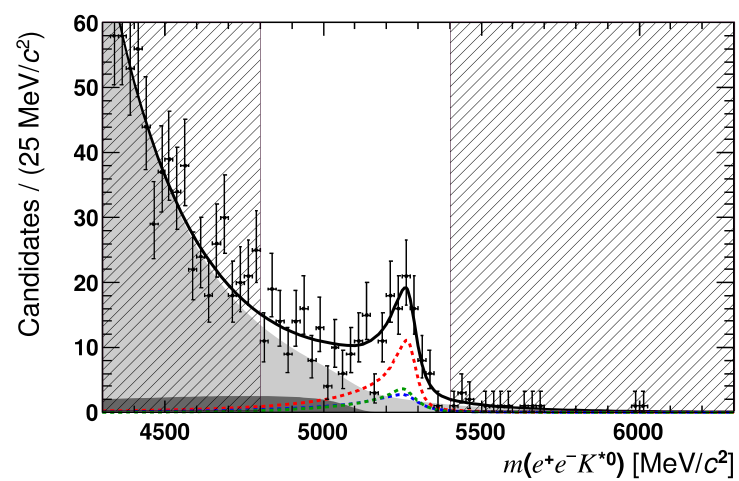
Why is it interesting? (compared to muons...)

- Because the low q^2 endpoint is at 10^{-6} GeV^2
  - Mainly photon pole contribution
  - Smallest form factor uncertainties

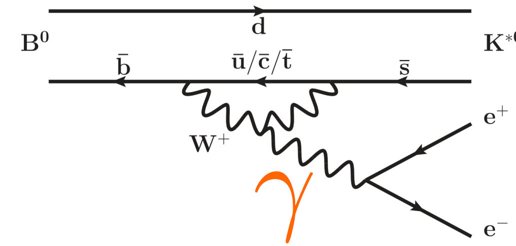
- You can make electrons at LHCb, but it's challenging
  - Cannot compete with muon sensitivity above 1 GeV^2
  - Yet, below 1GeV^2 we got enough candidates to do a 3D angular analysis

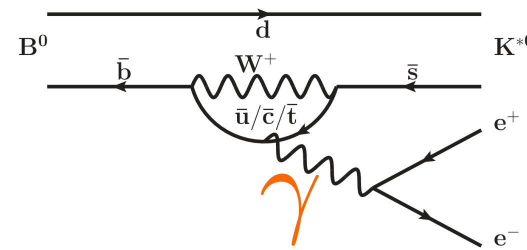




VERY low q^2

- **one q^2 bin chosen:** $[0.0004, 1]\,\mathrm{GeV}^2$
- completely negligible lepton mass
- "clean" large recoil region
- small $F_\mathrm{L} \rightarrow$ more sensitivity to $\mathrm{A}_\mathrm{T}^{(2)}$, $\mathrm{A}_\mathrm{T}^{\mathrm{Im}}$
- photon pole contribution dominating
- sensible to $\mathcal{C}_7$ Wilson coefficient
- and for $\frac{A_\mathrm{R}}{A_\mathrm{L}}$ small and real:
  $\mathrm{A}_\mathrm{T}^{(2)} \sim -2\frac{A_\mathrm{R}}{A_\mathrm{L}} \quad \Rightarrow \quad b \rightarrow s\gamma$ polarization!



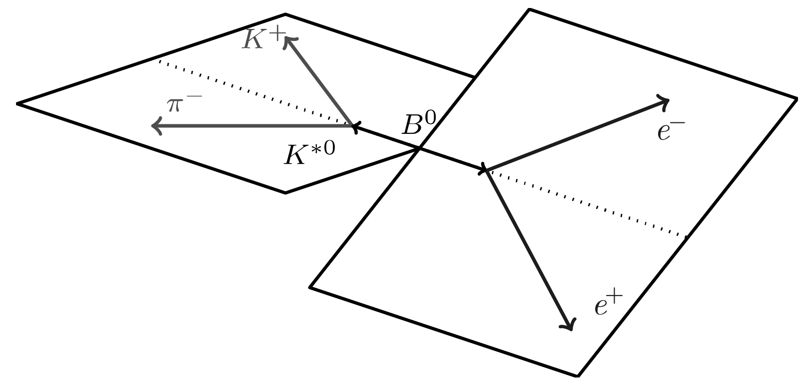


- loss of sensitivity on $\mathrm{A}_\mathrm{T}^{(2)}$ as a function of q^2 with $\frac{1-4m_\ell^2/q^2}{1+2m_\ell^2/q^2}$
- but above $1\,\mathrm{GeV}^2$ the μ mode has same sensitivity and higher yield in LHCb

Lower q^2 limit

The lower q^2 limit is experimentally driven

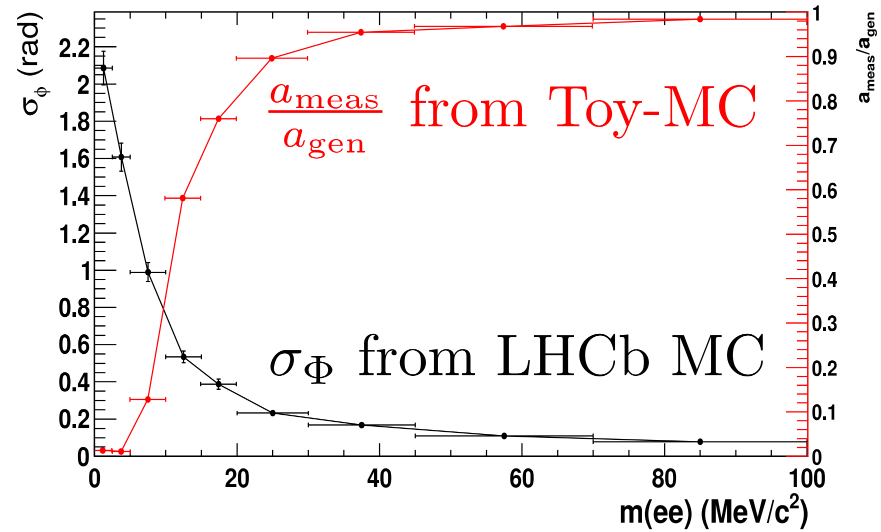
- angle between leptons gets very small
- ϕ is measured with bad resolution because of multiple scattering
- may bias the measurement of ϕ-related observables $A_T^{(2)}$ and A_T^{Im}



cut chosen at $20\,\mathrm{MeV}/c^2$
$\rightarrow$ integrated bias below 1%

It serves also as a veto to $B^0 \rightarrow K^{*0}\gamma$ with the γ conversion to e^+e^- in the material

- background with 100× higher BR
- after veto just ~ 4% pollution



Digression on K*gamma

K*g used as a control channel

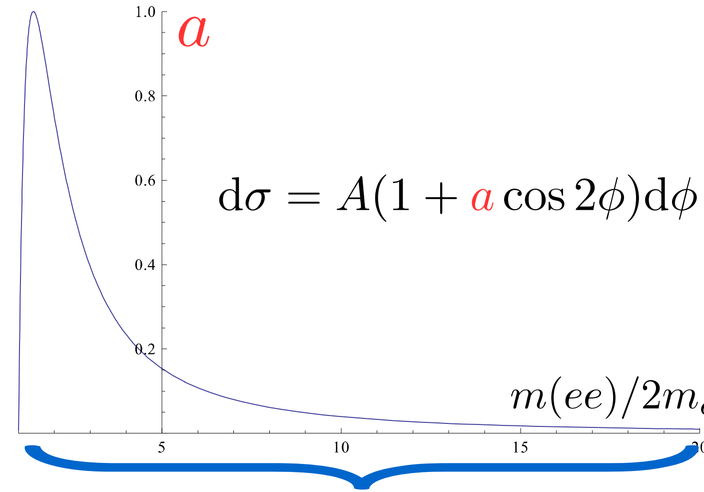
- Check mass shape
- Check fraction of partially hadronic bkg

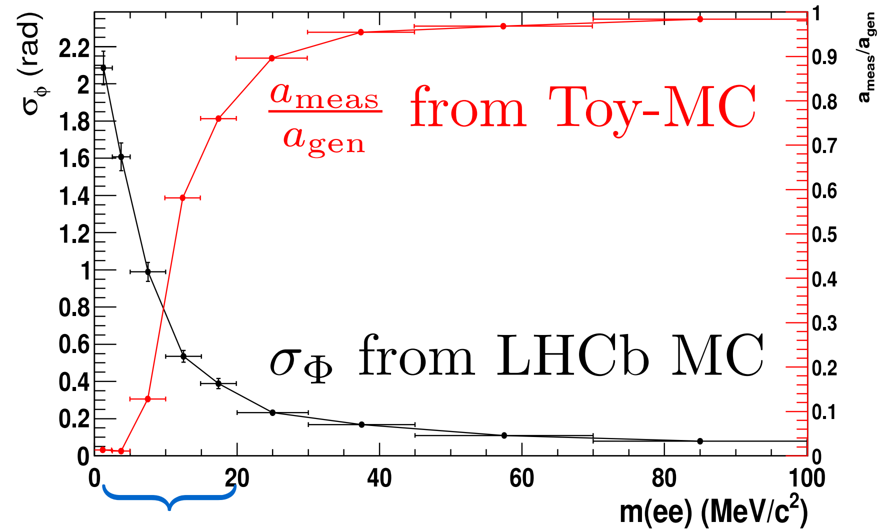
Question: can conversion electrons be used to measure photon polarization?

- The conversion pair plane contains the polarization information
  Wick `1951 Phys Rev 81 p467-468`
  using Weizsacker-Williams approximation:

$$d\sigma = \left(\frac{\beta r_0^2}{2x^2}\right)\{(1-\beta^2\cos^2\theta)^{-1} - \frac{1}{2} + 2\beta^2(1-\beta^2)$$
$$(1-\beta^2\cos^2\theta)^{-2}\sin^2\theta\cos^2\phi\}\sin\theta d\theta d\phi$$

- But this information is lost for $m(ee)$ masses above 10 MeV/c^2
  $\Rightarrow$ not feasible in LHCb, one would need a tracker with a much smaller X/X_0





Angular observables

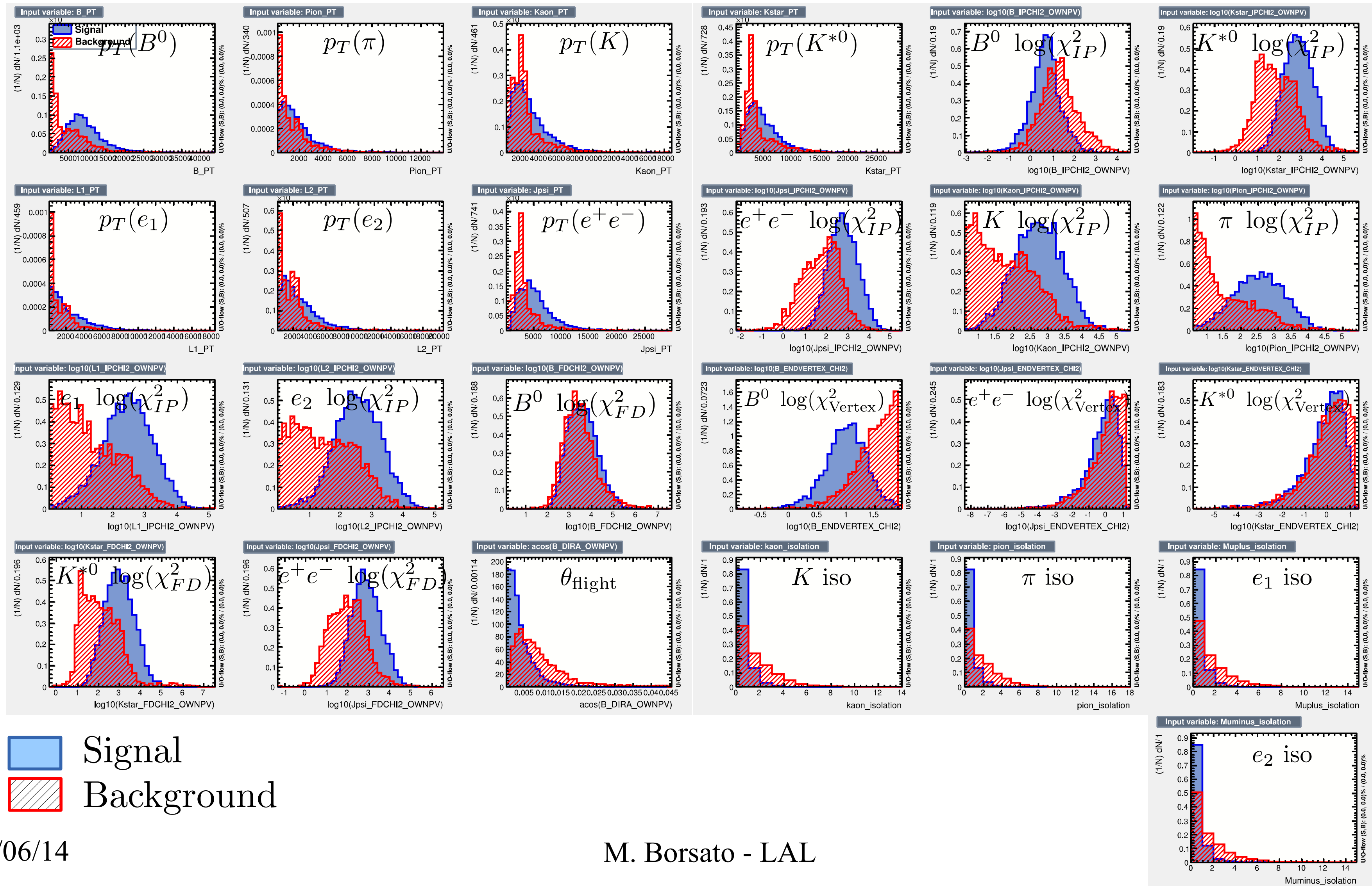
Folding: $\tilde{\phi} = \phi + \pi$ if $\phi < 0$ (and $\tilde{\phi} = \phi$ otherwise) $\rightarrow$ removes $J_{4,5,7,8}$

$$\frac{1}{\mathrm{d}(\Gamma+\bar{\Gamma})/\mathrm{d}q^2}\frac{\mathrm{d}^4(\Gamma+\bar{\Gamma})}{\mathrm{d}q^2\ \mathrm{dcos}\,\theta_\ell\ \mathrm{dcos}\,\theta_K\ \mathrm{d}} = \frac{9}{16\pi}\Bigg[\frac{3}{4}(1-F_\mathrm{L})\sin^2\theta_K + F_\mathrm{L}\cos^2\theta_K + \left(\frac{1}{4}(1-F_\mathrm{L})\sin^2\theta_K - F_\mathrm{L}\cos^2\theta_K\right)\cos^2\theta_\ell + \frac{1}{4}(1-F_\mathrm{L})\sin^2\theta_K\sin^2\theta_\ell\boxed{\cos 2\phi\ \mathrm{A}_\mathrm{T}^{(2)}} + (1-F_\mathrm{L})\sin^2\theta_K\boxed{\cos\theta_l\ \mathrm{A}_\mathrm{T}^\mathrm{Re}} + \frac{1}{2}(1-F_\mathrm{L})\sin^2\theta_K\sin^2\theta_\ell\boxed{\sin 2\phi\ \mathrm{A}_\mathrm{T}^\mathrm{Im}}\Bigg]$$

$\mathrm{A}_\mathrm{T}^{(2)}$, $\mathrm{A}_\mathrm{T}^\mathrm{Im}$, $\mathrm{A}_\mathrm{T}^\mathrm{Re}$
CP-averaged "clean" observables

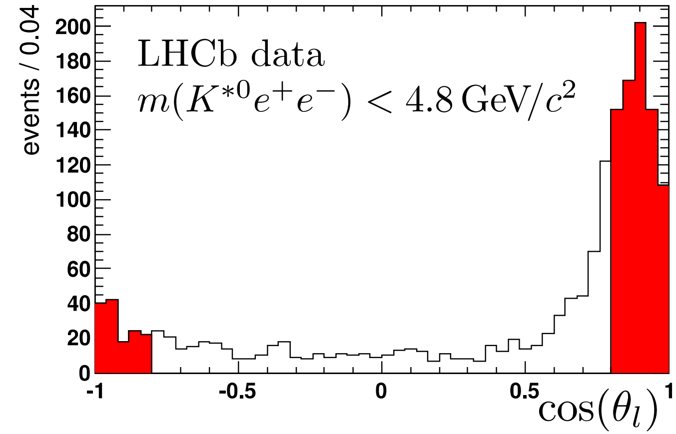
with other foldings measurements of observables such as P'_4, P'_5 is possible in principle

Boosted Decision Tree based selection

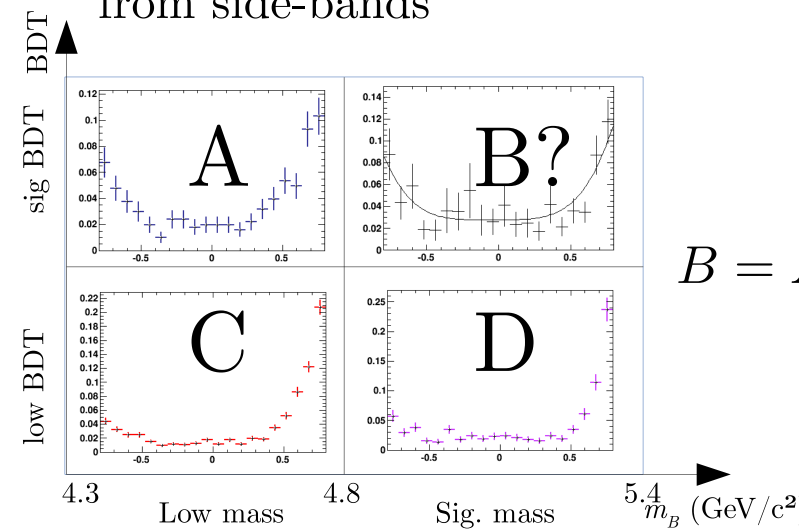


Backgrounds at LHCb

- $B_s^0 \to e^+e^-\phi(K^+K^-)$: cut $m(KK)$ (mis-id)
- $B^0 \to K^{*0}V(e^+e^-)$, $V = \rho, \omega, \phi$: $\sim 1\%$
- $B^0 \to K^{*0}\gamma$, converted γ : $\sim 4\%$
- $B^0 \to D^-e^+\nu$ (More energetic)
  $\hookrightarrow K^{*0}e^-\nu$
  - The background peaks at high $\cos\theta_\ell$
  - could cut on $m(K^{*0}e^-)$ but bias $\cos\theta_\ell$
  - Restrict $\cos\theta_\ell$ range not to bias A_T^{Re} $\Rightarrow$ loose 10% of signal, but $A_T^{(2)}$ (A_T^{Im}) measurement is not affected as it enters with $\sin^2\theta_\ell$



- Angular distribution extracted from side-bands



$$B = A\frac{D}{C}$$

LHCb sensitivity with 3 fb^{-1}

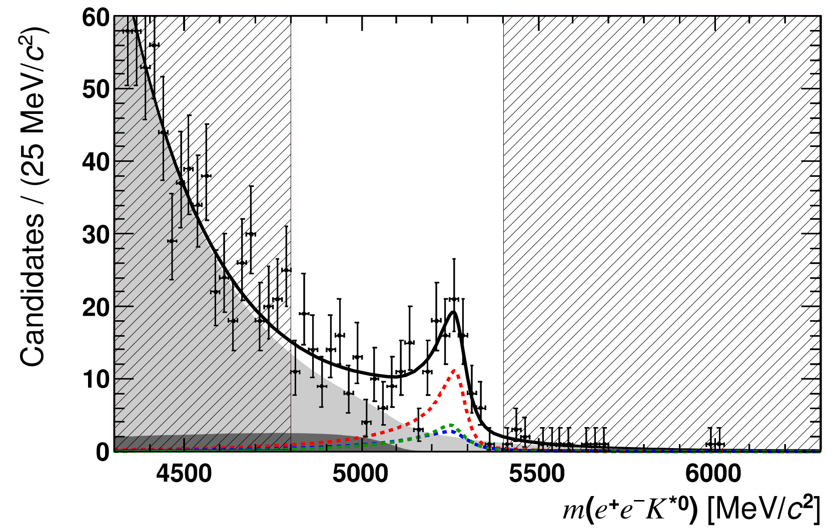
- $\sim$ **128 signal events** with $3\,\mathrm{fb}^{-1}$
  $\rightarrow \quad \frac{S}{B} \simeq 1, \quad \frac{S}{\sqrt{S+B}} \simeq 8$

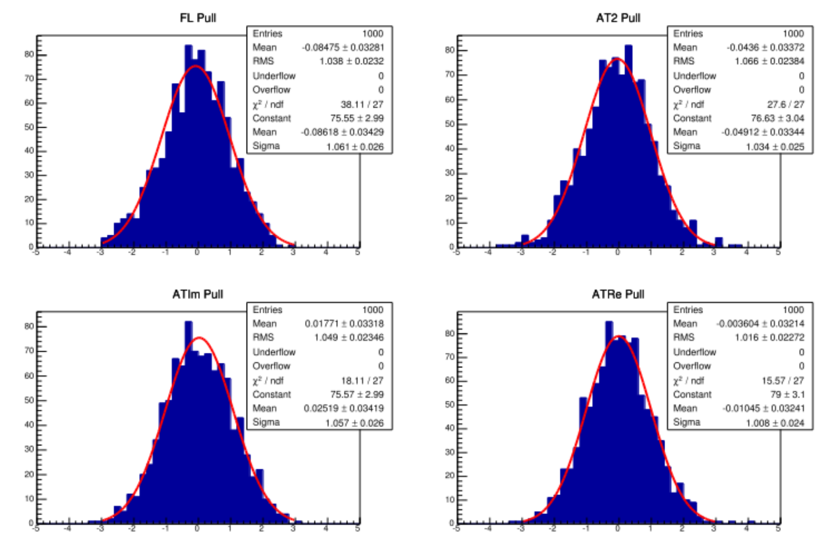
- $\sigma(\mathrm{A}_{\mathrm{T}}^{(2)}) \sim \frac{2}{1-F_{\mathrm{L}}}\sqrt{\frac{2}{N}}$

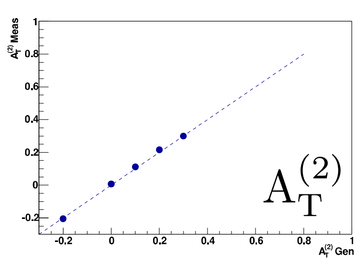
- from toy-MC of $S+B$:

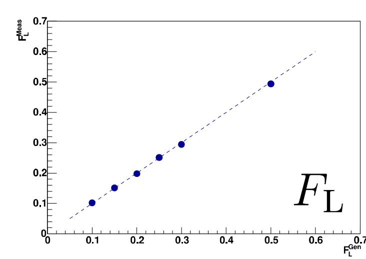
	F_{L}	$\mathrm{A}_{\mathrm{T}}^{(2)}$	$\mathrm{A}_{\mathrm{T}}^{\mathrm{Im}}$	$\mathrm{A}_{\mathrm{T}}^{\mathrm{Re}}$
σ_{stat}	0.069	0.249	0.248	0.172

- fit has good stability:









Systematics

Systematic errors from:

- Background angular modelling (from data sidebands)
- Angular acceptance modelization (from LHCb MC)
- ϕ is very hard to bias, acceptance is flat and so are background distributions
- The systematic takes just into account the degree of knowledge of this flatness

Combinatorial modeling systematics

	$F_{\rm L}$ pull	$\rm A_T^{(2)}$ pull	$\rm A_T^{Im}$ pull	$\rm A_T^{Re}$ pull
$+a_s, +a_c$	-0.045	0.156	0.168	0
$-a_s, -a_c$	-0.029	-0.204	-0.192	0.012
$+a_1^K$	-0.141	-0.070	0.045	0.037
$-a_1^K$	-0.007	-0.009	-0.041	0.045
$+a_3^\ell + a_4^\ell$	-0.185	-0.011	-0.061	0.182
$-a_3^\ell - a_4^\ell$	0.103	0.046	-0.052	-0.309

Part. hadronic modeling systematics

	$F_{\rm L}$ pull	$\rm A_T^{(2)}$ pull	$\rm A_T^{Im}$ pull	$\rm A_T^{Re}$ pull
$F_{\rm L}^{\rm part} = 0$	-0.315	-0.025	0.006	0.020
$F_{\rm L}^{\rm part} = 0.33$	0.151	-0.036	0.009	-0.002

$$\sigma_{\rm tot} = \sigma\sqrt{1 + {\rm pull}^2}$$

	$F_{\rm L}$	$\rm A_T^{(2)}$	$\rm A_T^{Im}$	$\rm A_T^{Re}$
+pull	+0.103	+0.156	+0.168	+0.182
−pull	-0.232	-0.201	-0.192	-0.309

Measurement statistically driven

Impact of the measurement

- $b \to s\ell\ell$ analysis
- Bin $[0.0004, 1]\,\mathrm{GeV}^2$
- $< q^2 >= 0.2\,\mathrm{GeV}^2$ one can use this to estimate correction due to terms others than $\mathcal{C}_7/\mathcal{C}_7'$
- measurement of four clean observables

	F_L	$\mathrm{A}_\mathrm{T}^{(2)}$	$\mathrm{A}_\mathrm{T}^{\mathrm{Im}}$	$\mathrm{A}_\mathrm{T}^{\mathrm{Re}}$
σ_stat	0.069	0.249	0.248	0.172

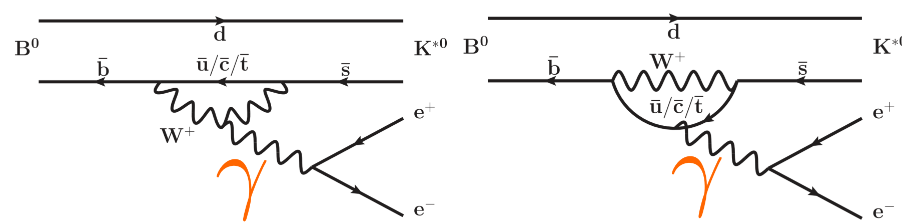
- May measure other observables like $P'_{4,5}$ but sensitivity and systematics were not explored yet

- $b \to s\gamma$ analysis
- A_R/A_L to the 10% level (if it is small and real)

$$\Rightarrow \quad \sigma\left(\frac{A_R}{A_L}\right) \sim \frac{\sigma(\mathrm{A}_\mathrm{T}^{(2)})}{2} \sim 0.12$$

- $\lim_{q^2\to 0} \mathrm{A}_\mathrm{T}^{(2)} = \frac{2\mathcal{R}e(C_7^{\mathrm{eff}} C_7'^{\,\mathrm{eff}*})}{|C_7^{\mathrm{eff}}|^2 + |C_7'^{\,\mathrm{eff}}|^2}$

$$\lim_{q^2\to 0} \mathrm{A}_\mathrm{T}^{\mathrm{Im}} = \frac{2\mathcal{I}m(C_7^{\mathrm{eff}} C_7'^{\,\mathrm{eff}*})}{|C_7^{\mathrm{eff}}|^2 + |C_7'^{\,\mathrm{eff}}|^2}$$



Summary and conclusions

- Angular analysis of $B^0 \to e^+e^-K^{*0}$ at very low q^2 at LHCb is being finished and looks promising
- In $3\,\mathrm{fb}^{-1}$ we got ~ 128 events with $S/B \sim 1$
- Measurement is statistically driven
- Expect a sensitivity on $\mathrm{A}_{\mathrm{T}}^{(2)}$ and $\mathrm{A}_{\mathrm{T}}^{\mathrm{Im}}$ of 0.25
- Real γ converting in e^+e^- not usable for polarization (in LHCb)
- Unblinding will hopefully happen soon
- Plan to have results ready at the end of summer