Bottom-quark Fusion Processes at the LHC for Probing Z' Models and B-meson Decay Anomalies

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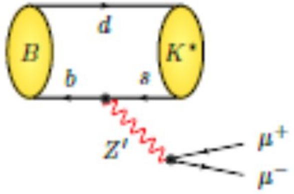
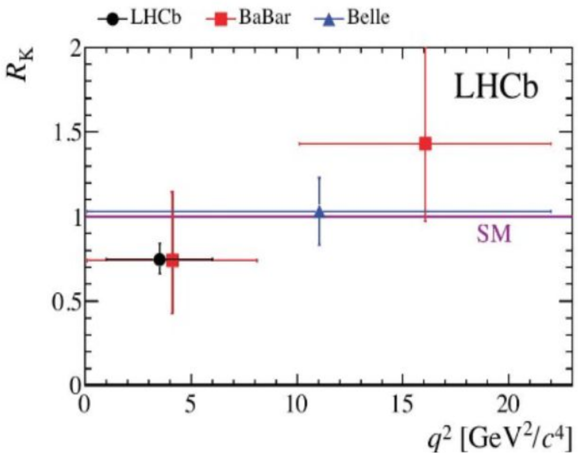
ICHEP2018 Seoul

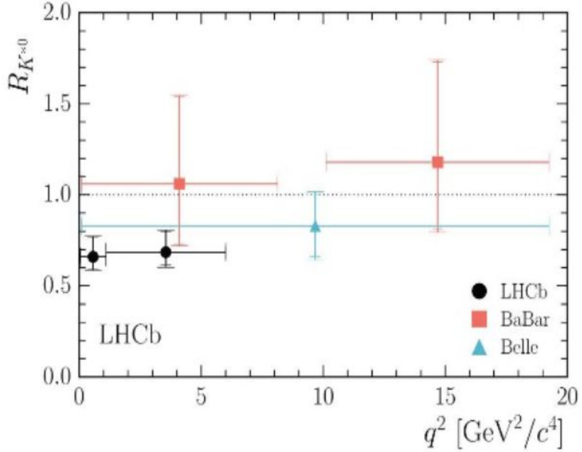
Physics model and context

- Recent LHCb results shows certain deviation from SM prediction for R_K/R_{K^*}
- Combining this results with other anomalies observed in $b \to s\mu\mu$ transition we can obtain up to 4σ tension with SM
- See Lorenzo Capriotti talk

New contributions to $b \to s\mu\mu$ transition can be explained in various BSM theories, in particular involving Z'







Physics model and context

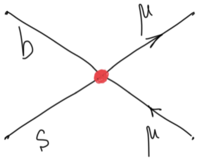
New Physics contribution to B decays can be described by following Lagrangian:

$$\mathcal{L} \supset \frac{4G_F}{\sqrt{2}} V_{tb} V_{ts}^* \frac{e^2}{16\pi^2} C_9 O_9 + h.c.$$

where effective operator O_9,

$$O_9 = (\bar{s}\gamma_\mu P_L b)(\bar{\mu}\gamma_\mu \mu)$$

stands for 4-fermion interaction:



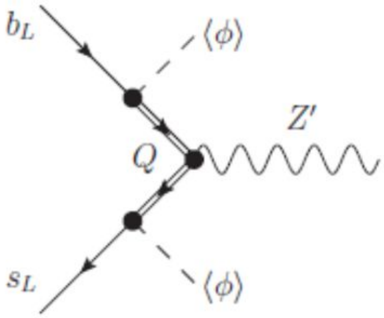
and best fit value for corresponding Wilson coefficient is: $C_9 = -1.56^{+0.46}_{-0.56}$

Physics model and context

Minimal Lagrangian:

$$\mathcal{L} \supset Z'_\mu \left[\quad g_\mu \, \bar{\mu} \, \gamma^\mu \, \mu + \, g_\mu \, \bar{\nu_\mu} \, \gamma^\mu \, P_L \, \nu_\mu + \quad g_b \sum_{q=t,b} \bar{q} \, \gamma^\mu \, P_L \, q \, + (\, g_b \, \delta^L_{bs} \, \bar{s} \, \gamma^\mu \, P_L \, b \, + \, \text{h.c.} \,) \,) \right]$$

Many models can produce such lagrangian, e.g. using VLQ:



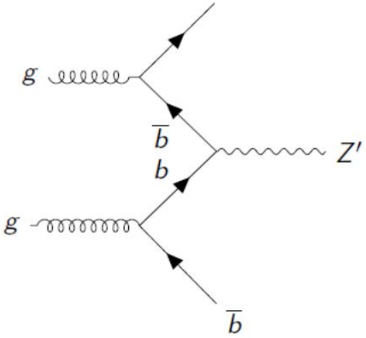
- Selective *U(1)* fermion charges to evade current LHC and LEP boundaries
- Only needs to couple to muons in leptonic sector and *b*-*s* in fermionic sector
- Add muon neutrino and top quark couplings to preserve *SU(2)*
- Can also consider ditau decays

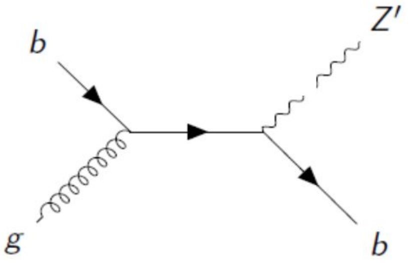
Production at the LHC

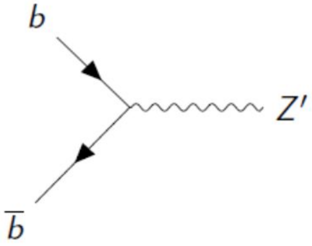
BFF: Bottom Fermion Fusion

$$\sigma(pp \to Z' \to \mu\,\mu) \sim \frac{2\,g_b^2\,g_\mu^{V\,2}}{6\,g_b^2 + 3g_\mu^{V\,2}}$$

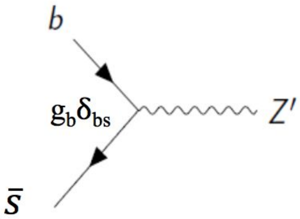
$$\sigma(pp \to Z' \to b\,\bar{b}) \sim \frac{3\,g_b^4}{6\,g_b^2 + 3g_\mu^{V\,2}}$$







Similarly, one can have Bottom-Strange fusion to probe:



Final states at the LHC

- Add up Z' decays and ISR particles

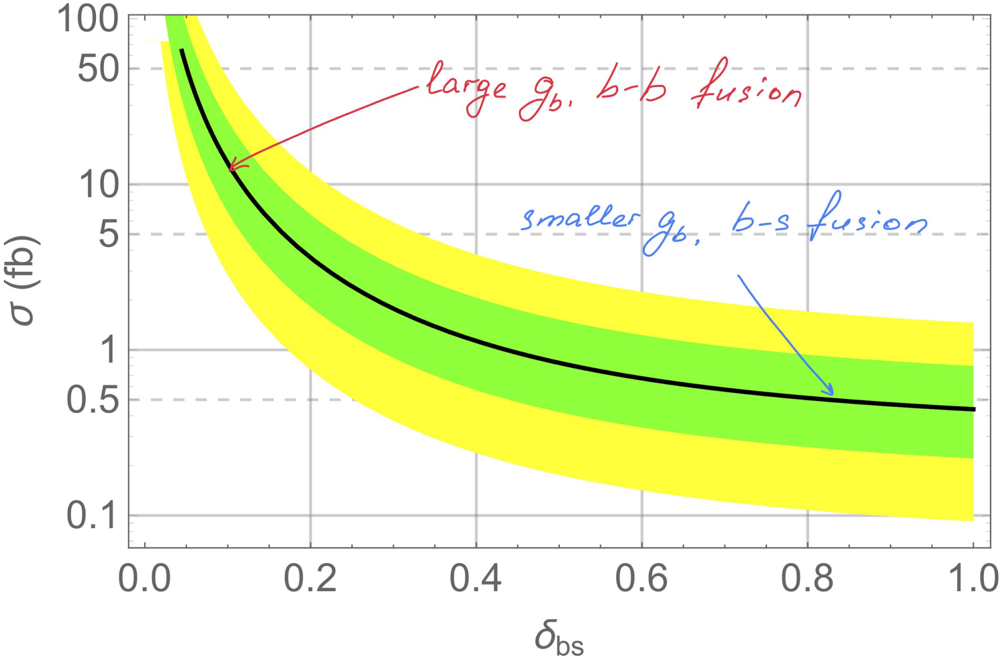
- Z' decays:
  - di-quarks: pairs of *b* and, if kinematically allowed, *t* quarks
  - di-leptons
    - In principle, only muons and muon neutrinos will be enough
    - di-tau can be considered too

- ISR particles:

# ISR jets	process	description
0	*b-b fusion*	both *b* from sea quarks
0	*b-s fusion*	*b* and *s* from sea quarks
1	*b-b fusion*	one *b* from gluon splitting and one *b* from sea quarks
1	*b-s fusion*	one *b* from gluon splitting and one *s* from sea quarks
2	*b-b fusion*	both *b* from gluon splitting

Production XS matching B-anomalies

$$g_b \delta_{bs} g_\mu (100GeV/m_{Z'}) \approx 1.3 \times 10^{-5}$$



$$\sigma(\, pp \to Z' \ \to \mu\, \mu\,) \ \propto 2\, g_b^2 (1 + k\delta_{bs}^2)\, {g_\mu}^2$$

$$\sigma(\, pp \to Z' \ \to b\, \bar{b}\,) \ \propto 3\, g_b^4 (1 + k\delta_{bs}^2)$$

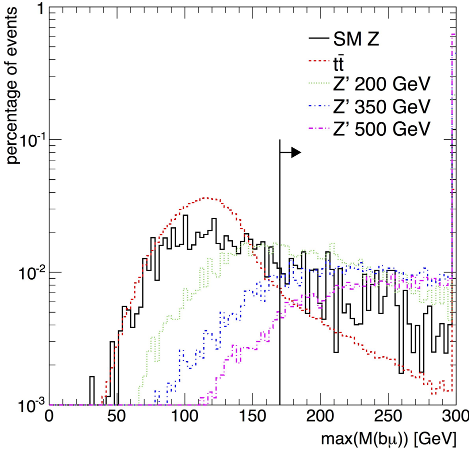
Search strategy

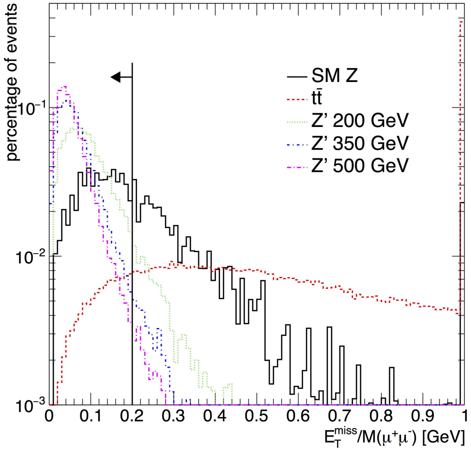
- Focus on di-muon final state
- Use ISR jets to reduce the background contamination
- Main backgrounds:
  - SM Z + jets
  - Top pair production

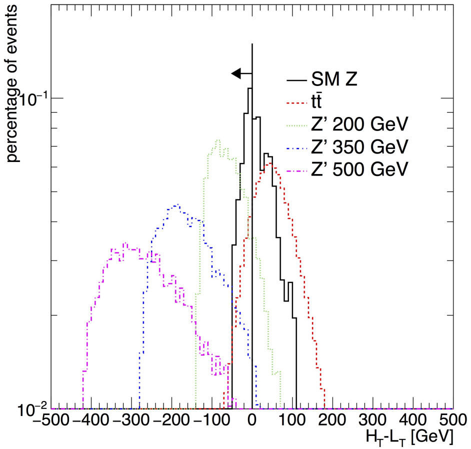
- Ask for two opposite sign muons
- At least two jets with at least one b-tagged
  - Helps to remove DY
- Apply top mass bound and MET cuts
  - Reduce top pair contribution
- Select events with high leptonic activity (HT-LT<0)

Search strategy

	preselection	$M_{\mu b}$	$H_{\mathrm{T}} - L_{\mathrm{T}}$	$E_{\mathrm{T}}^{\mathrm{miss}}/M(\mu^+\mu^-)$
$t\bar{t}$	8%	17%	26%	27%
SM Z	0.2%	41%	32%	54%
Z' 200	7%	60%	74%	89%
Z' 350	10%	90%	90%	97%
Z' 500	13%	92%	94%	98%

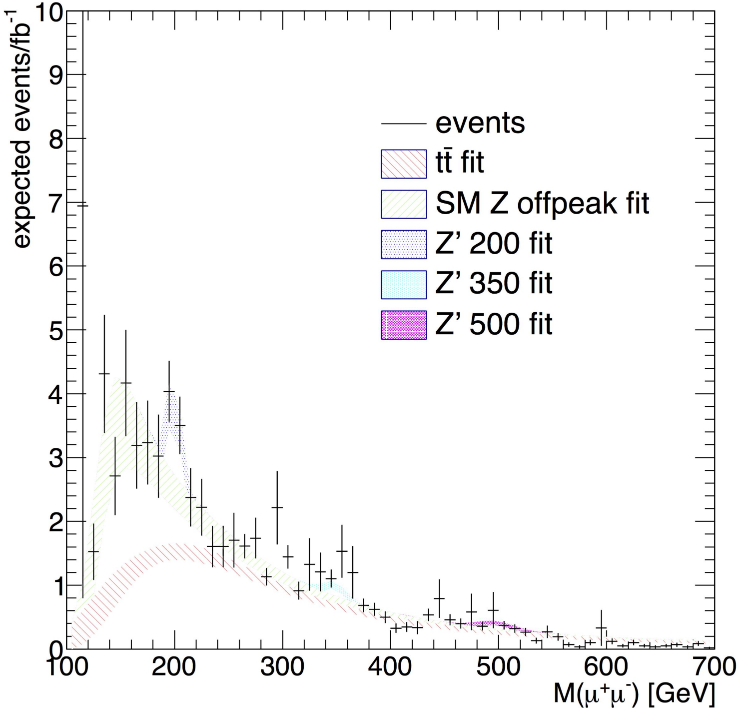




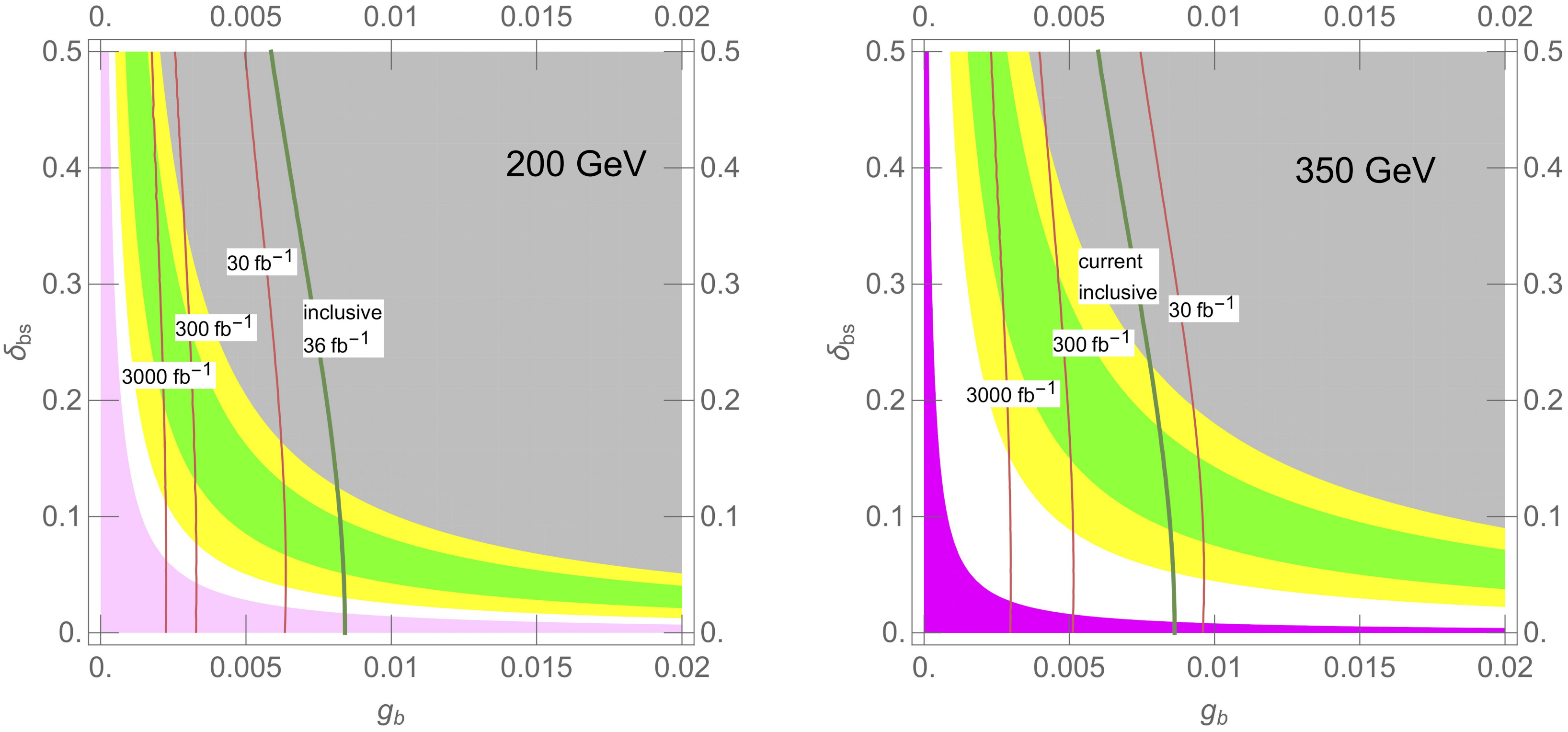


Limits estimation

- ☑ Provide shapes for each signal and background process
- ☑ Take into account shape uncertainties
- ☑ Use Profile Likelihood estimator
- ☒ Delphes-only simulation
- ☒ Systematic uncertainties aren't accounted for
- ☒ Pile-up contribution is not accounted for



Projected sensitivity



We expect much improved sensitivity w.r.t. Inclusive searches around 200 GeV dilepton invariant mass