On Light Mediators in B Decay Anomalies & Dark Matter

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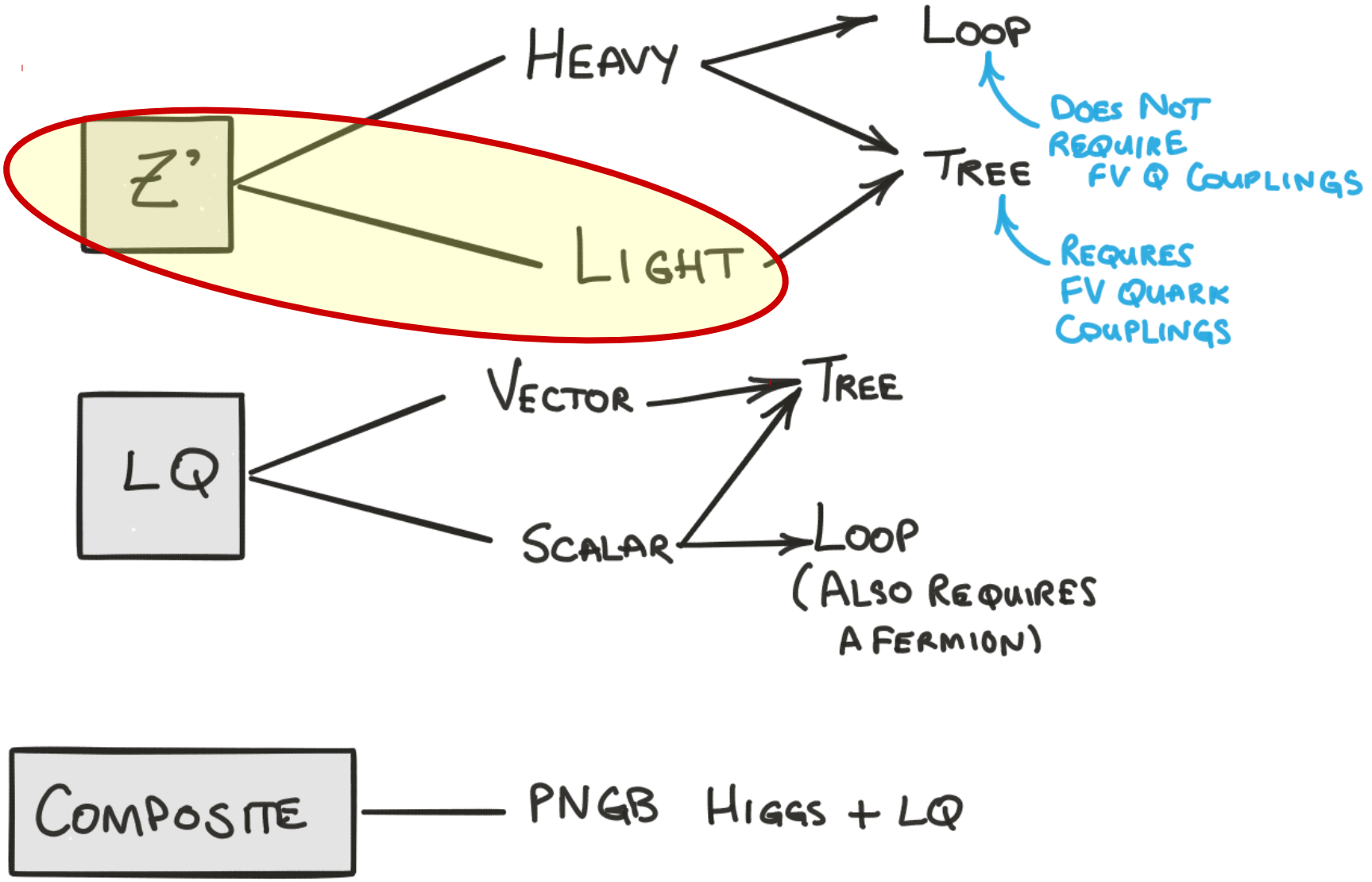
26 September 2017
Flavour & Dark Matter – Heidelberg

Based on: 1705.03465 FB, U. Haisch, P. Monni

Focus of the talk



Additional thanks to David Straub, Filippo Sala, Brian Shuve, Yotam Soreq, & Susanne Westhoff for fruitful discussions

The light NP ansatz

> The possibility that a light resonance could be responsible for the anomaly in P_5' was mentioned by Amarjit Soni at 50th Rencontres de Moriond EW 2015, and subsequently re-emphasised to one of the authors by Brian Batell in a private conversation.

[Uli Haisch]

- Fuyuto, Hou, Kohda: [1512.09026]
- Sala, Straub: [1704.06188]
- Ghosh: [1704.06240]
- Alok, Bhattacharya, Datta, Kumar, Kumar,London: [1704.07397]
- Datta, Liao, Marfatia: [1702.01099]

A simplified model

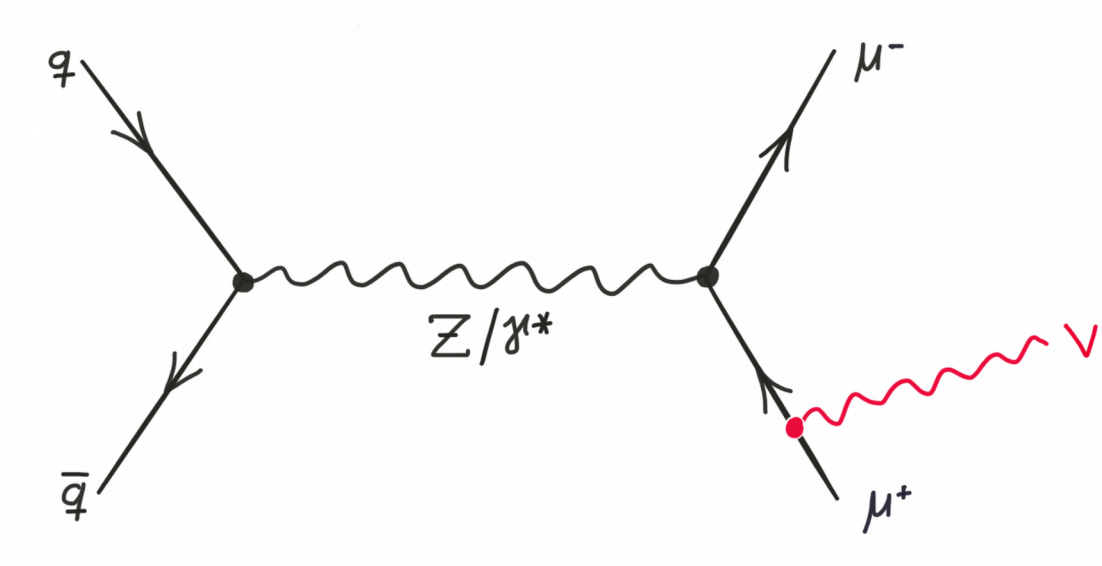
Sala, Straub: [1704.06188]

$$\mathcal{L} \supset \left(g_L^{sb}\,\bar{s}_L \not{V} b_L + \text{h.c.}\right) + \bar{\mu}\left(g_V^{\mu} - g_A^{\mu}\gamma_5\right)\not{V}\mu + g_V^{\chi}\,\bar{\chi}\not{V}\chi$$

$$g_\chi \gg g_V^\mu,\ g_A^\mu$$

$$\frac{\Gamma_V}{m_V} \approx \frac{{g_V^\chi}^2}{12\pi}$$

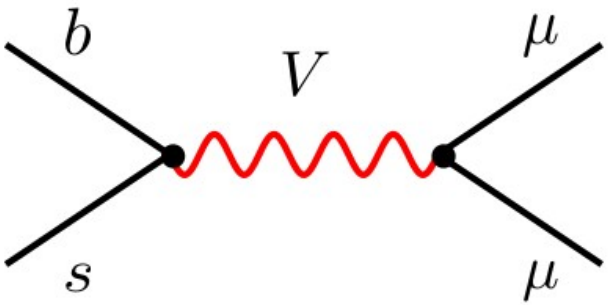
$$\text{Br}(V \to \mu\mu) \approx \frac{{g_V^\mu}^2 + {g_A^\mu}^2}{{g_V^\chi}^2}$$

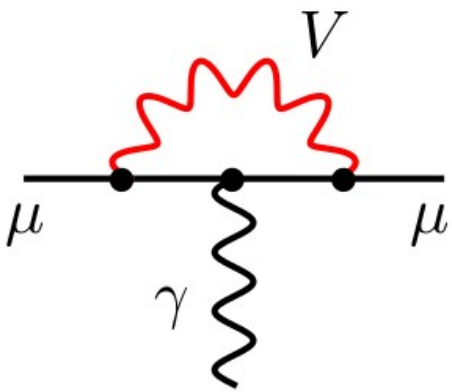


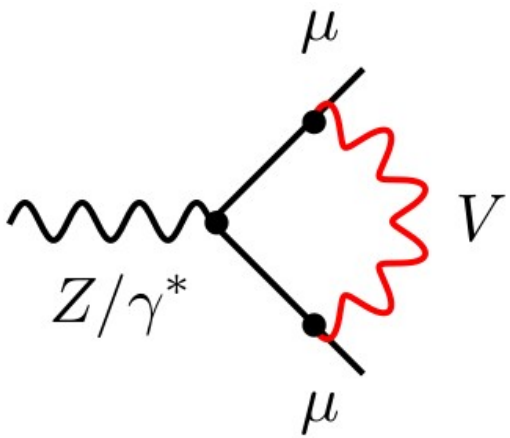
For $\Gamma_V/m_V \sim 20\%$, $g_V^\chi \sim 3$, and $\text{Br}(V \to \mu\mu) \sim 10^{-3}$

A (general) simplified model

- In general, an example of a light spin 1 di-muon resonance
- Contributes to anomalous magnetic moment
- Modifies Drell-Yan production

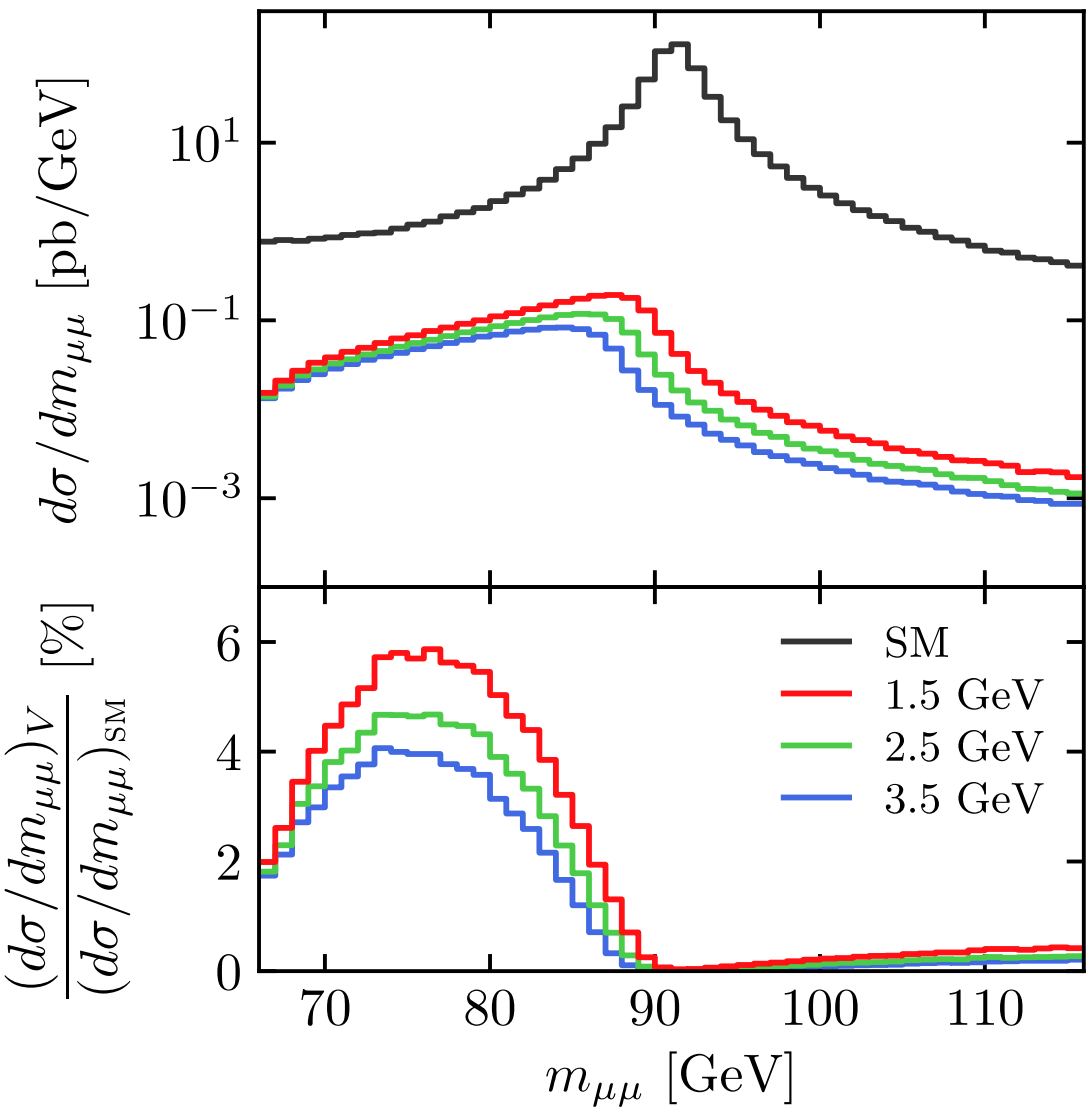




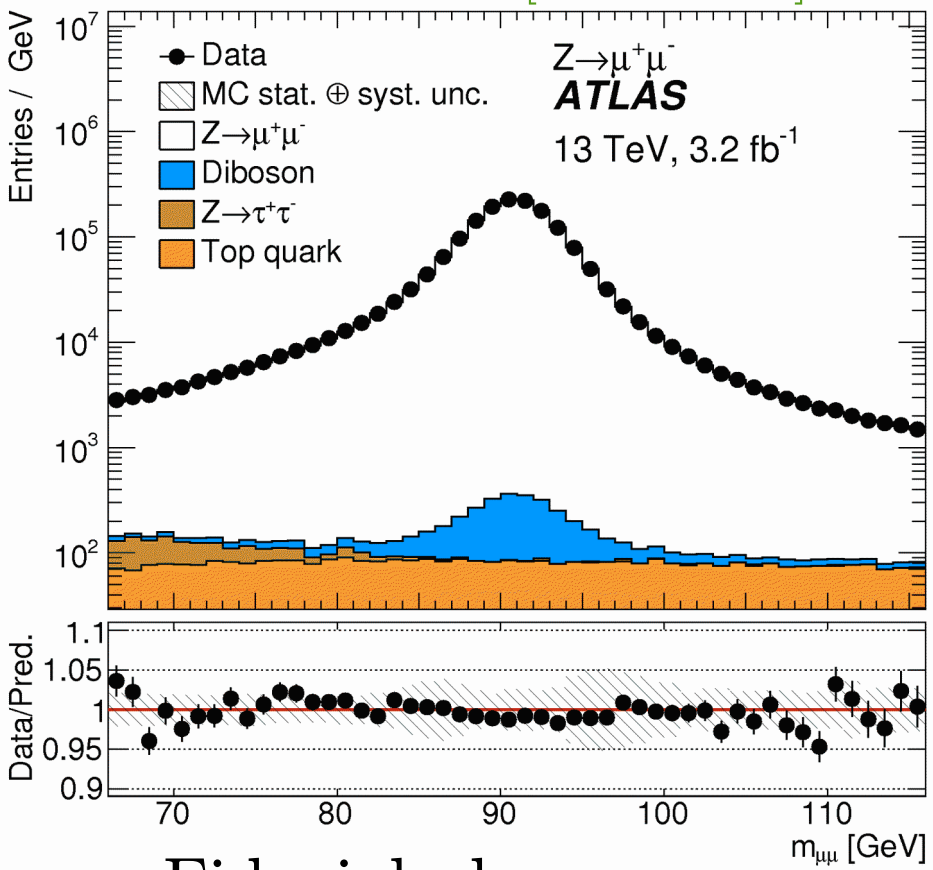


P_5', R_K, R_{K^*} $\quad$ $a_\mu = ((g-2)/2)_\mu$ $\quad$ DY

Z lineshape



ATLAS: [1612.03636]



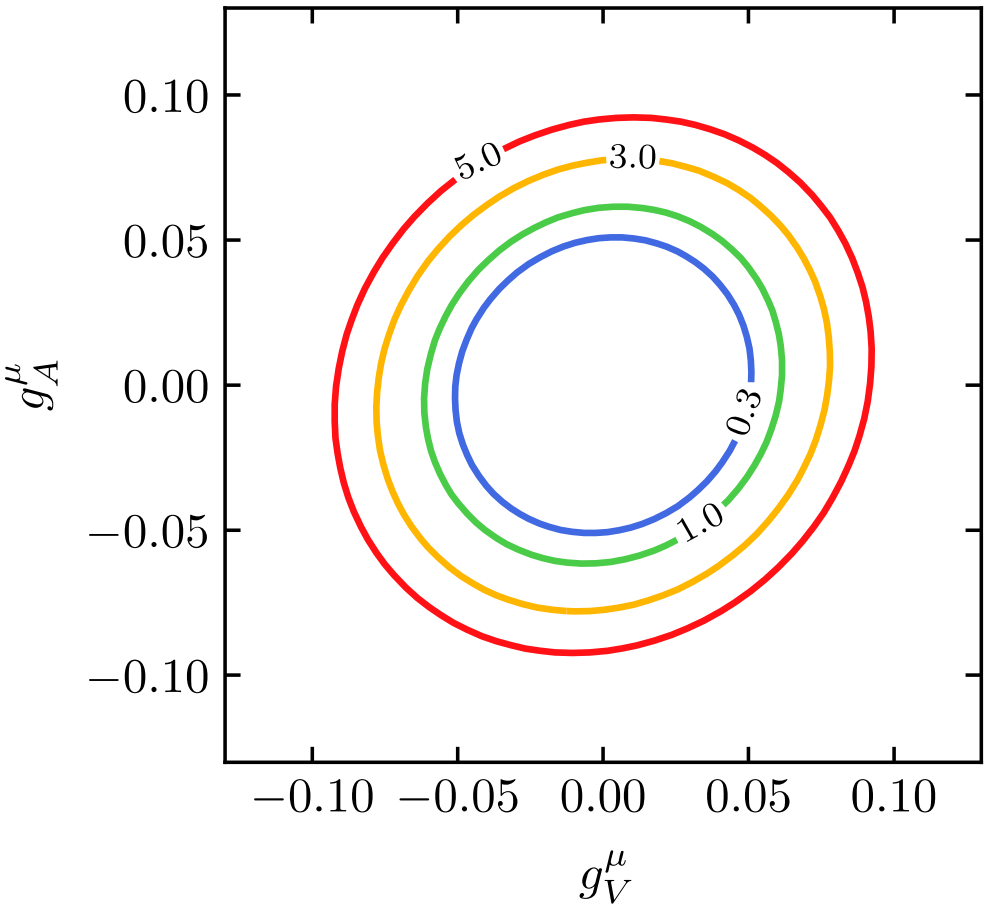
Fiducial phase space

$p_T^{\mu} > 25$ GeV

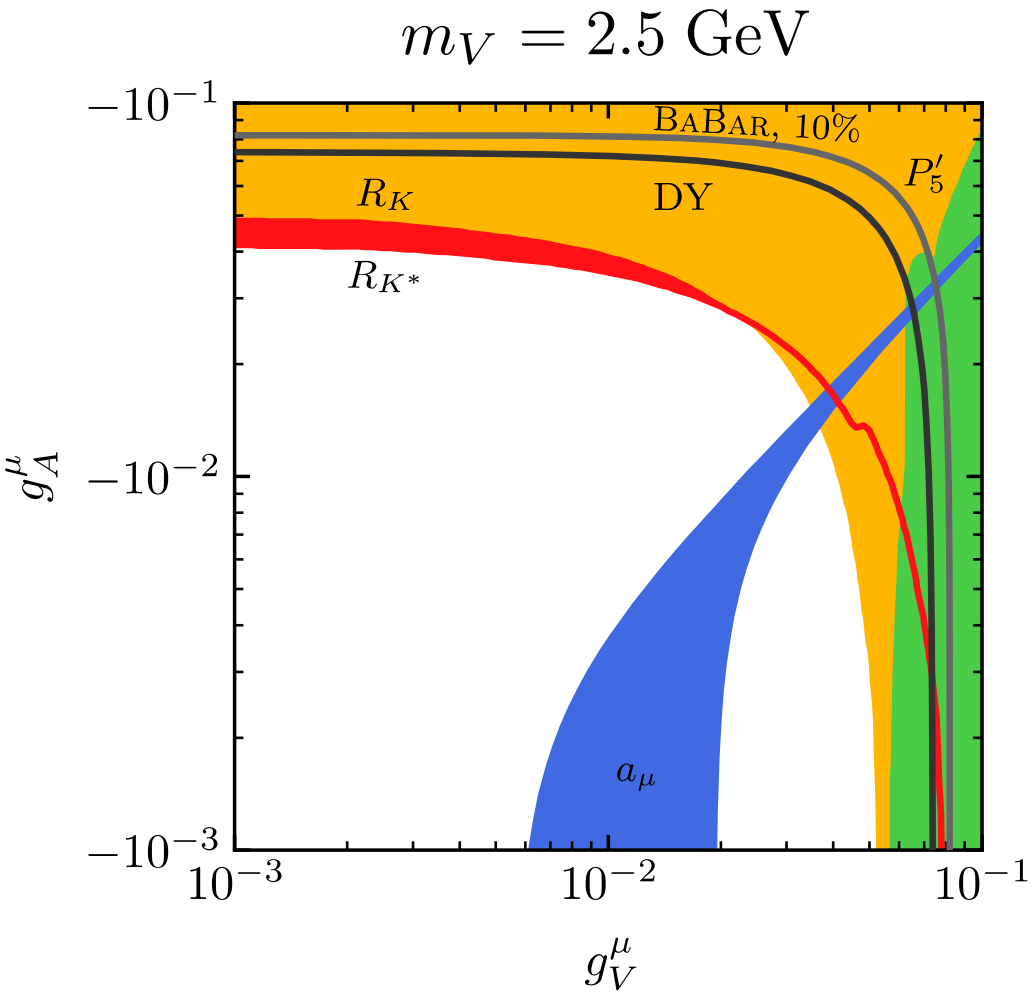
$|\eta_{\mu}| < 2.5$

$66 < m_{\mu\mu} < 116$ GeV

Derived constraint

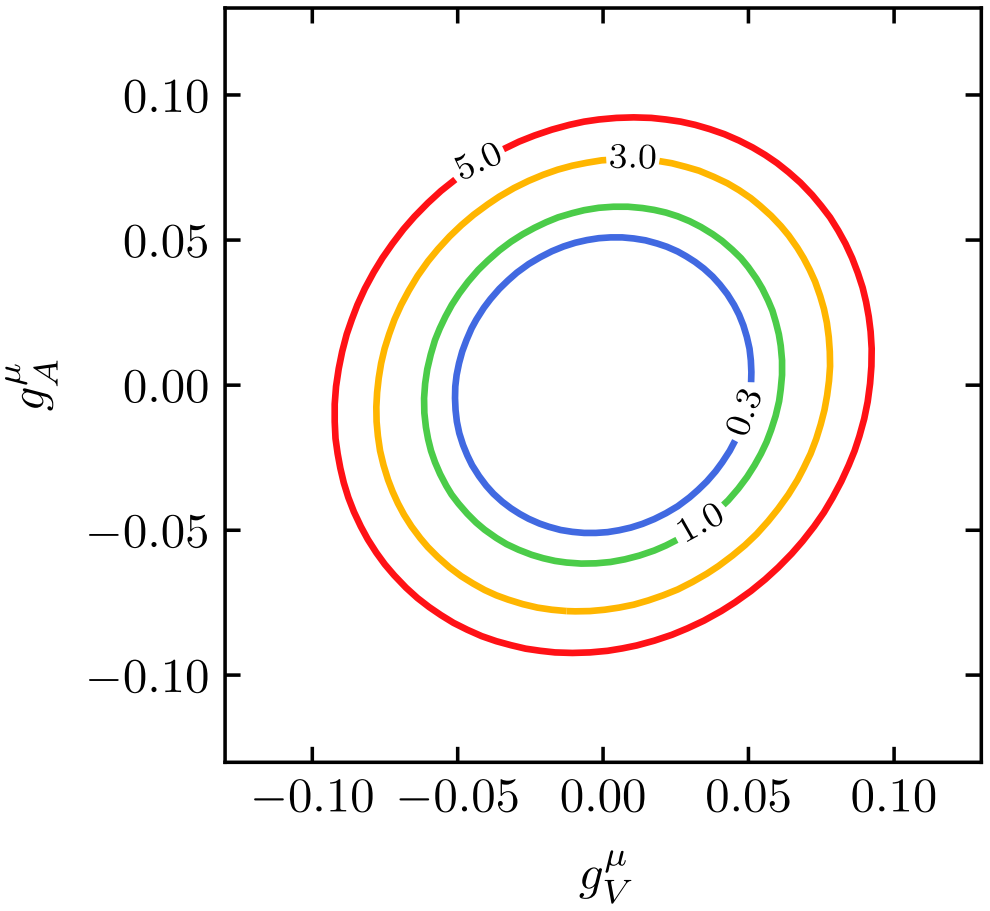


95% CL contours for various masses in GeV



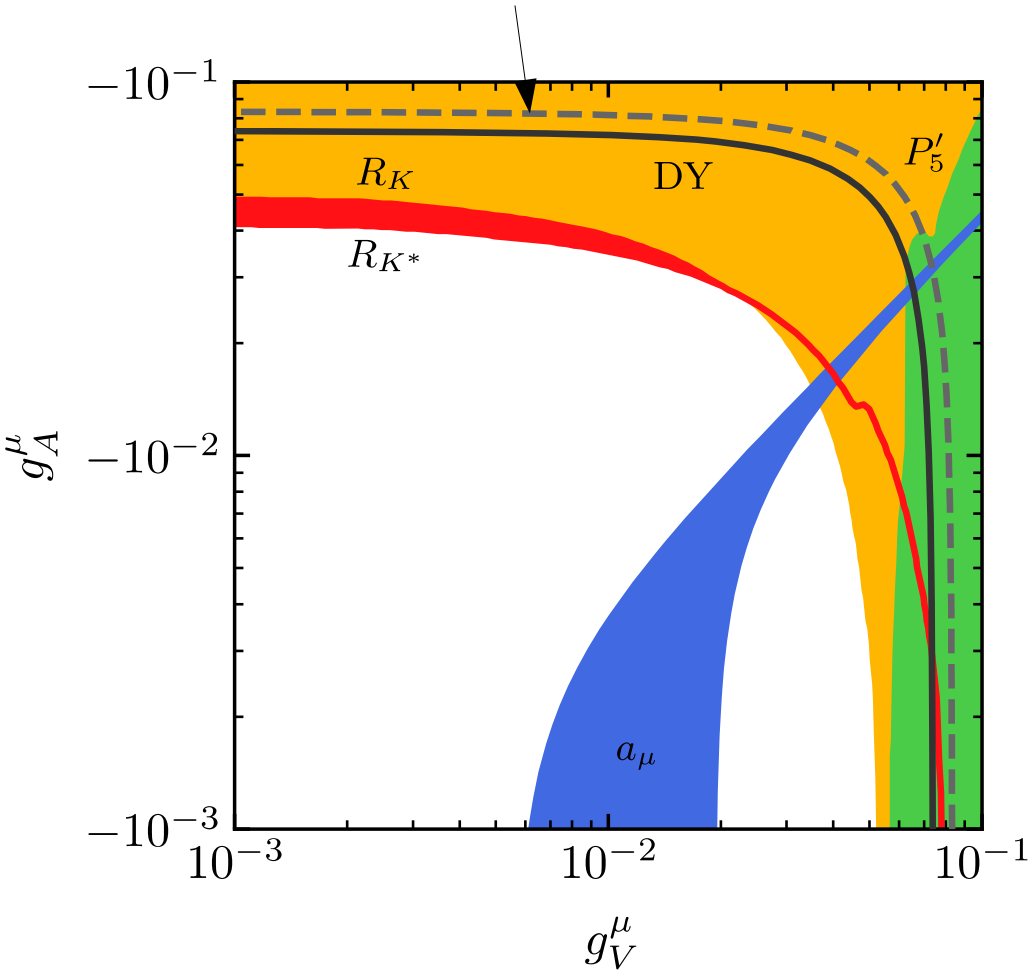
B anomaly preferred regions taken from: Sala, Straub, [1704.06188] $g_{bs} = -1.5 \times 10^{-8}$

Derived constraint



95% CL contours for various masses in GeV

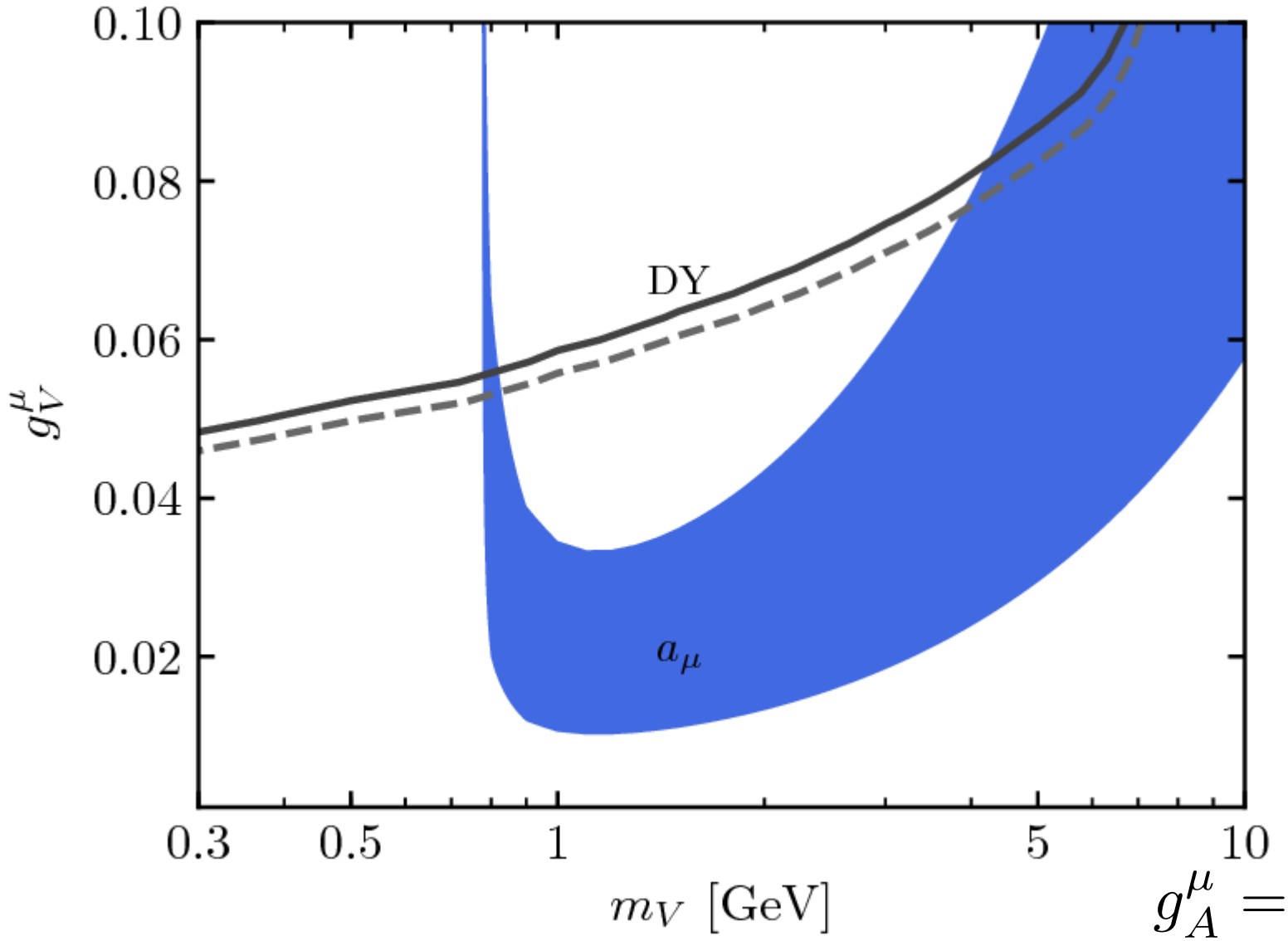
Adding uncorrelated 2.1% luminosity uncertainty



B anomaly preferred regions taken from: Sala, Straub, [1704.06188] $g_{bs} = -1.5 \times 10^{-8}$

$(g-2)\mu$

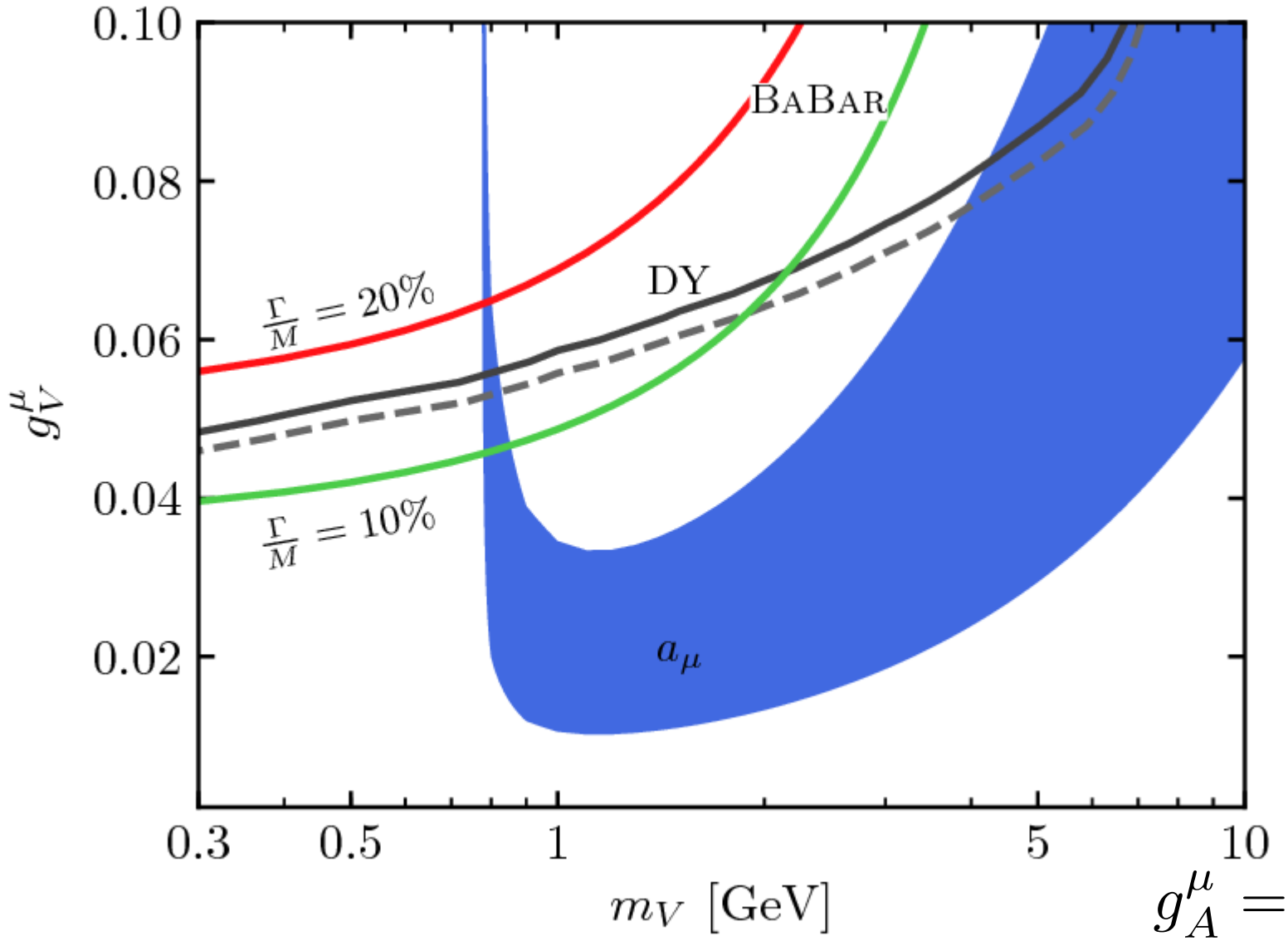
$$\Delta a_\mu \equiv a_\mu^{\rm exp} - a_\mu^{\rm SM} = \frac{x}{12\pi^2}\left[g_V^2\, f(x) + g_A^2\, g(x)\right], \quad \text{with} \quad x \equiv \frac{m_\mu^2}{m_V^2}$$



$$g_A^\mu = 0.41 g_V^\mu$$

$(g-2)\mu$

$\Delta a_\mu = (287 \pm 80) \times 10^{-11}$ PDG 2016



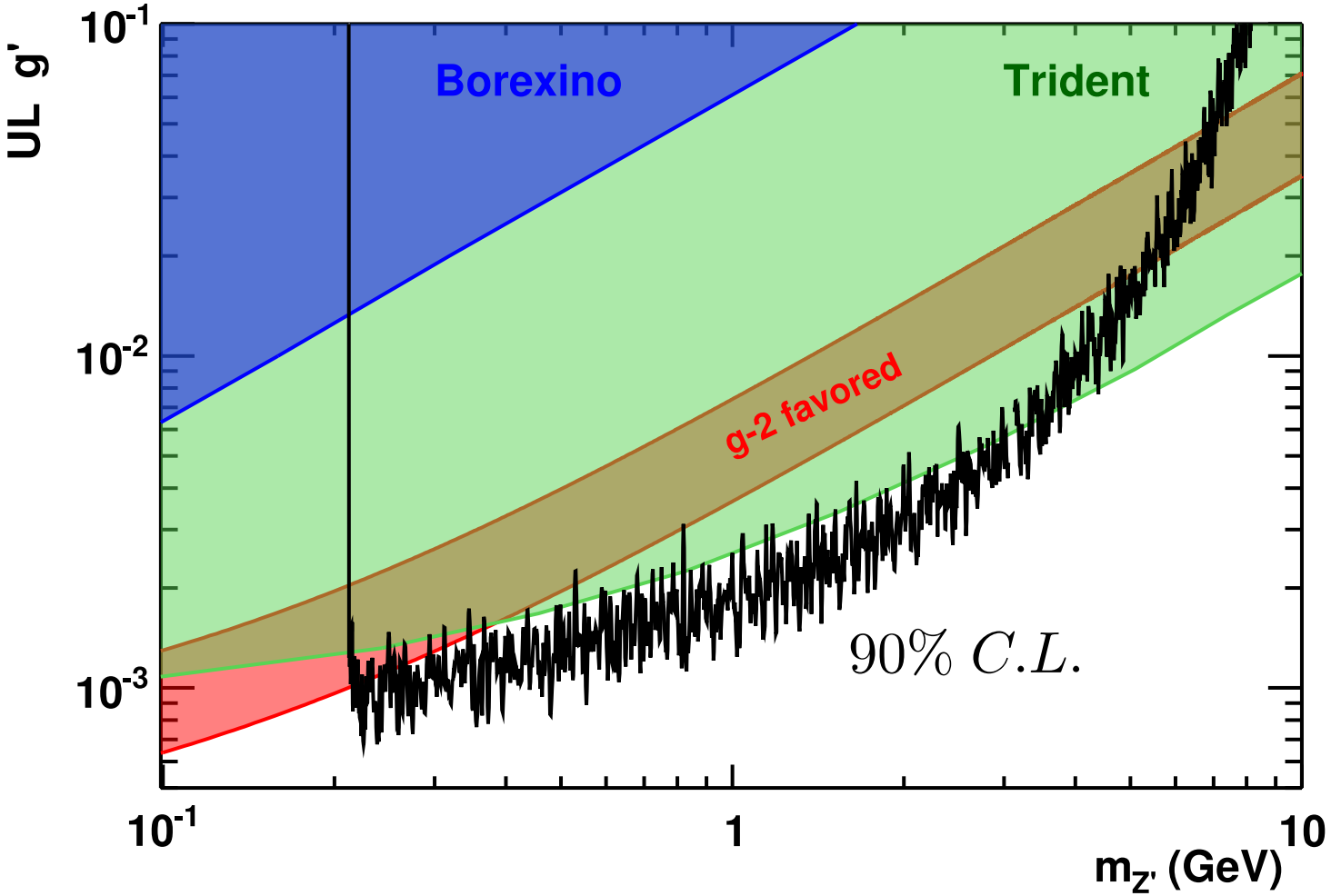
$g_A^\mu = 0.41 g_V^\mu$

The BaBar bound

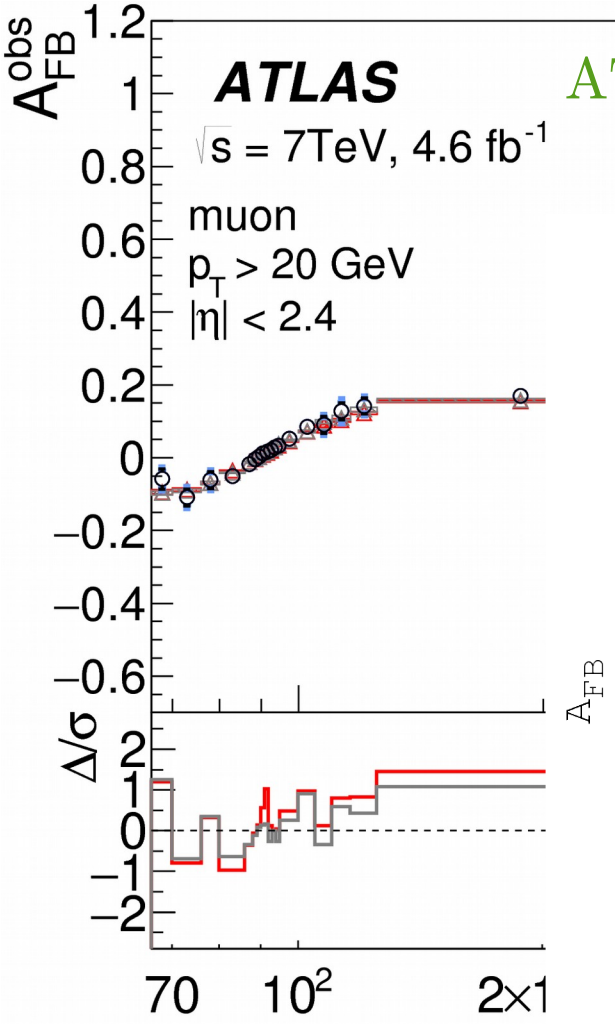
Brian Shuve [private comm.]

BaBar [1606.03501]

Benchmark model: gauged $L_\mu - L_\tau$
Look for $e^+e^- \to 4\mu$
For us, recast it by Br

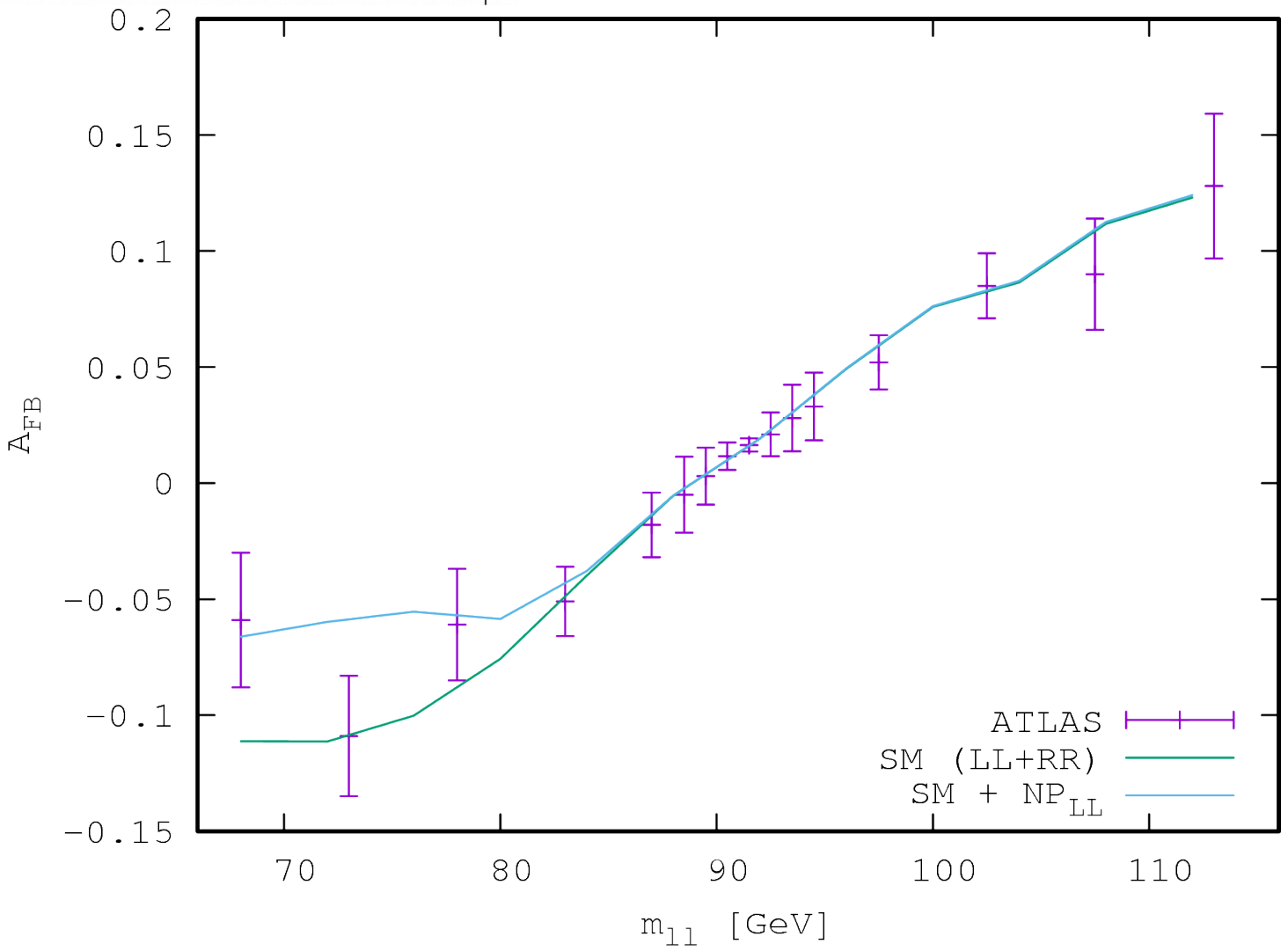


Forward-backward asymmetry



ATLAS [1503.03709]

N.B.: more precise measurement by LHCb [1509.07649]



AFB definition

$$\mathcal{A}_{\mathrm{FB}} = \frac{N_{\theta^*_{\mathrm{CS}}>0} - N_{\theta^*_{\mathrm{CS}}>0}}{N_{\theta^*_{\mathrm{CS}}<0} + N_{\theta^*_{\mathrm{CS}}<0}}$$

$$\cos\theta^*_{\mathrm{CS}} = \frac{p_{z,\ell\ell}}{\|p_{z,\ell\ell}\|} \frac{2\left(p_1^+ p_2^- - p_1^- p_2^+\right)}{m_{\ell\ell}\sqrt{m_{\ell\ell}^2 + p_{T,\ell\ell}^2}}$$

$$p_i^{\pm} = \frac{1}{\sqrt{2}}\left(E_i \pm p_{z,i}\right)$$

Summary and outlook

- LHC measurements provide relevant constraints for light NP
- Many precision observables: $m_{\ell\ell}$, A_{FB}, ϕ^*, ...
- Use ratios (like normalized distributions) to reduce luminosity & PDF uncertainties
- Careful treatment of higher order effects needed for precise bound

Thank you!