# Search for muon-philic new light gauge boson at Belle II

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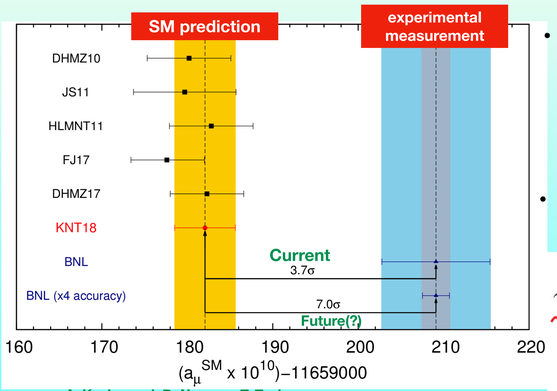
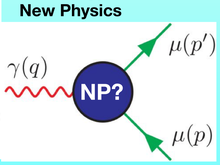
[JHEP 10 (2018) 168] [arXiv:1904.13053 [hep-ph]]

Motivated by the long-lasting 3.5σ discrepancy in the anomalous magnetic moment of muon, we consider a new muon-specific force mediated by a light gauge boson, X, with mass $m_X < 2m_\mu$ and the coupling constant $g_X \sim (10^{-4} - 10^{-3})$ We show that the Belle II experiment has a robust chance to probe such a light boson in $e^+e^- \to \mu^-\mu^+X$ channel and cover the most interesting parameter space explaining the discrepancy with the planned target luminosity, 50 ab^−1.

## Muon g-2 SM prediction & Measurement



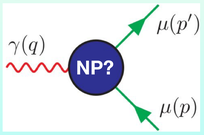

- 3.7 sigma discrepancy between SM prediction and exp. measurement (Re-confirmation or Dispute of muon g-2 by Fermilab in 2020)
- Very sensitive to various types of New Physics




A. Keshavarzi, D. Nomura, T. Teubner
[PRD 97 (2018) 11, 114025]
[1802.02995]

## Muon g-2 and New Physics

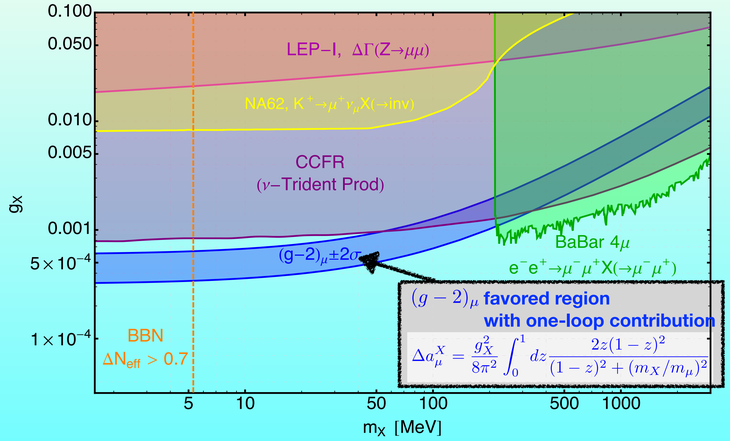
- Various New Physics Possibilities have been suggested and None of them are experimentally confirmed so far.
  - We focus on MeV-GeV scale (with small coupling) New Physics
    - Dark photon with kinetic mixing — Severely constrained by recent dark photon searches (e.g. NA64)
      M. Pospelov [PRD 80 (2009) 095002] [0811.1030]
    - Flavor-specific light gauge boson (ex: $U(1)_{L_\mu - L_\tau}$ )
      X.-G. He, G.C. Joshi, H. Lew, R.R. Volkas [PRD 44 (1991) 2118]
      S. Baek, N. G. Deshpande, X.-G. He, P. Ko [PRD 64 (2001) 055006] [0104141]



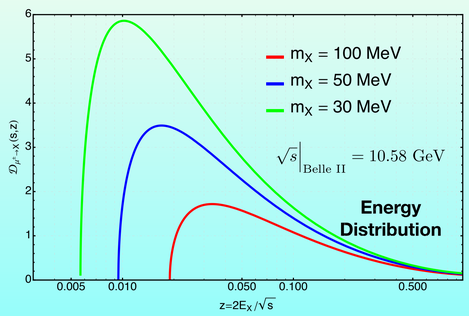

$$\mathcal{L} \supset \mathcal{L}_{\rm SM} - \frac{1}{4}X_{\mu\nu}X^{\mu\nu} + \frac{m_X^2}{2}X_\mu X^\mu - g_X X_\mu J_X^\mu$$

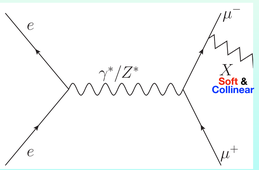
$$J_X^\mu = \bar\mu\gamma^\mu\mu - \bar\tau\gamma^\mu\tau + \bar\nu_\mu\gamma^\mu\nu_{\mu L} - \bar\nu_\tau\gamma^\mu\nu_{\tau L}$$

## Existing Constraints




## "dimuon+missing E ($\mu^-\mu^+ + E_{\rm miss}$)" channel




$$\frac{d\sigma_{\mu\mu X}(s)}{dz} = \sigma^{(0)}_{\mu\mu}(s)\cdot 2\mathcal{D}_{\mu^\pm\to X}(s,z)$$

$$\mathcal{D}_{\mu^\pm\to X}(s,z) = \frac{g_X^2}{8\pi^2}\frac{1+(1-z)^2}{z}\left[\ln\frac{sz^2}{4m_X^2} + 2\ln\left(1-\sqrt{1-\frac{4m_X^2}{sz^2}}\right)\right]$$

- Soft/Collinear emissions are dominant, due to the double-logarithmic IR divergence for the light gauge boson emission.

P. Ciafaloni, D. Cornelli, A. Riotto, F. Sata, A. Strumia
[JCAP 03 (2011) 019]
[1009.0224]

## SM Backgrounds

$i)\ \not{E}_T > 1.67$ GeV, $ii)\ m^2_{\rm miss} < 0.4\ {\rm GeV}^2/c^4$

$$e^-e^+ \to \tau^-\tau^+(\to \mu^-\mu^+\nu_\mu\nu_\tau\bar\nu_\mu\bar\nu_\tau)$$

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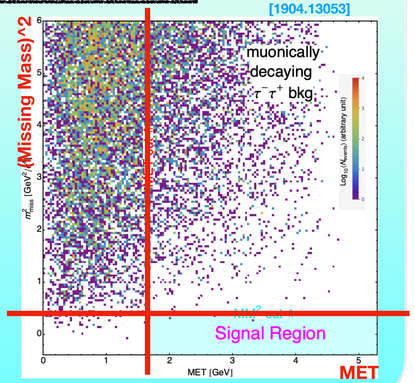
[1904.13053]

- dimuon + large Missing E
- Missing Mass is typically larger than $\mathcal{O}(1)$ GeV
- With kinematic cuts of MET and Missing Mass, remaining event number is $N_{\rm bkg} \sim \mathcal{O}(1)$ even at $\int dt\mathcal{L} = 50\ {\rm ab}^{-1}$

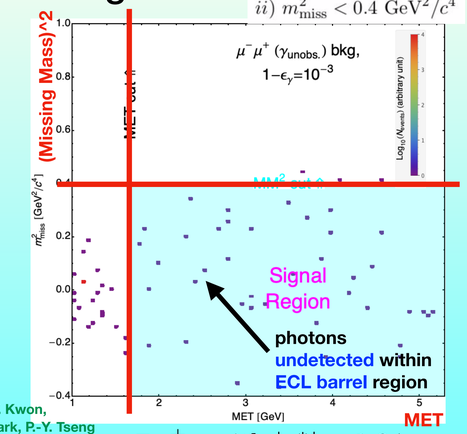



## SM Backgrounds

$i)\ \not{E}_T > 1.67$ GeV, $ii)\ m^2_{\rm miss} < 0.4\ {\rm GeV}^2/c^4$

$$e^-e^+ \to \mu^-\mu^+\gamma$$

- from soft/collinear photons or unobserved in the detection region
- large MET cut can remove all of collinear backgrounds
- High photon detection efficiency is needed to suppress unobserved backgrounds

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$\mu^-\mu^+\gamma$ with $|\eta^*_\gamma| < 1.94$

## Signal Event Distribution

$$e^-e^+ \to \mu^-\mu^+X$$

$i)\ \not{E}_T > 1.67$ GeV, $ii)\ m^2_{\rm miss} < 0.4\ {\rm GeV}^2/c^4$

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[JHEP 10 (2018) 168]
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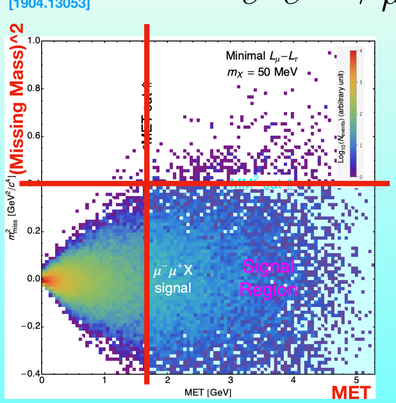
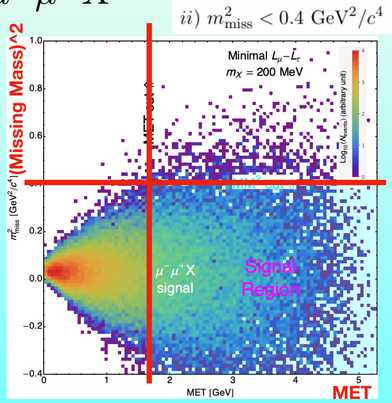



$m_X = 50$ MeV




$m_X = 200$ MeV

## Expected Sensitivity Limit

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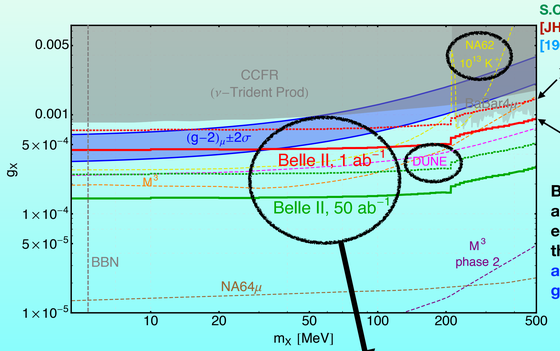
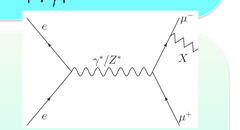
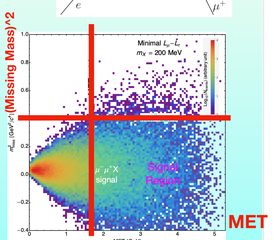
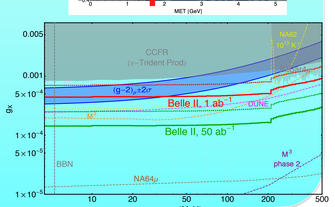
[1904.13053]




Belle II, NA62, DUNE and other fixed-target experiments can confirm the muon g-2 scenario with a new light muon-philic gauge boson.

The resulting sensitivity limit depends on the systematicuncertainties.

## Conclusion

- Muon g-2 shows a long-lasting discrepancy between SM prediction and measurements, strongly implying various New Physics possibilities.
- A light gauge boson weakly coupled to muon explain muon g-2. Especially, muon-specific light gauge boson can be explored with the "dimuon+Missing E" channel search at low-E electron-positron colliders.
- We suggest that Belle II have discovery potential and muon g-2 favored region can be explored, although it requires high photon detection efficiency to suppress backgrounds. The expected sensitivity limit is comparable to other approved future-coming experiments (NA62, DUNE, etc.)