

# Light new physics at Mu $\tilde{3}$ e

**Kevin Langhoff**

(with Simon Knapen, Toby Opferkuch, and Diego Redigolo)

[[2311.17915](#), [2311.17913](#)]

DPF-PHENO 2024 (May 13, 2024)

# Motivation for Mu3e

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Consider the process  $\mu^+ \rightarrow e^+ e^+ e^-$  coming from a dim-6 operator, e.g.  $\mathcal{O} = \frac{(\bar{\mu}e)(\bar{e}e)}{\Lambda^2}$ .

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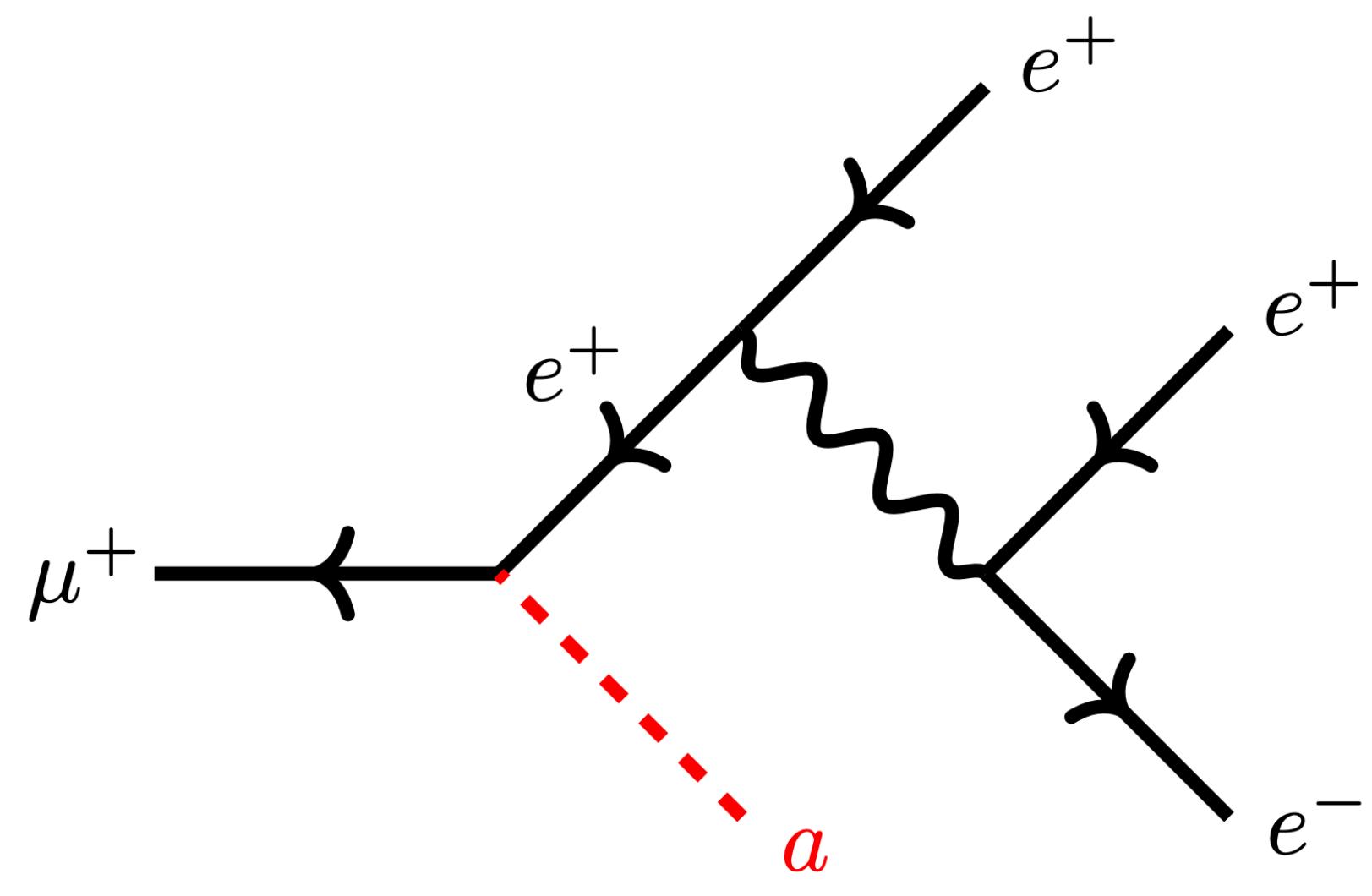
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This is the main search at the experiment Mu3e.

**What else can we look for at Mu3e?**

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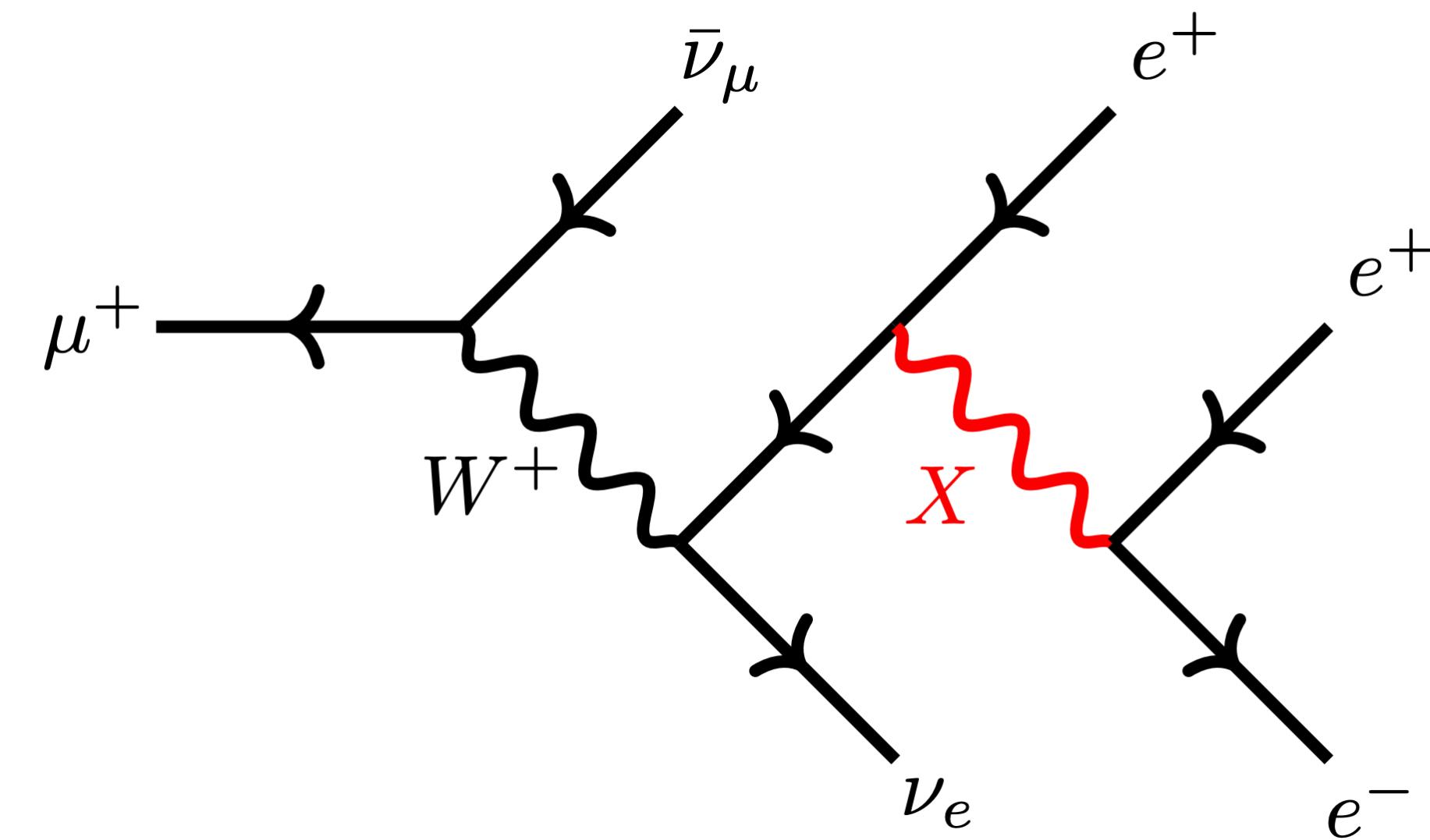
Flavor violating



[Perrevoort, [1812.00741](#) ]

[Knapen, **KL**, Opferkuch, Redigolo, [2311.17915](#)]

Flavor conserving

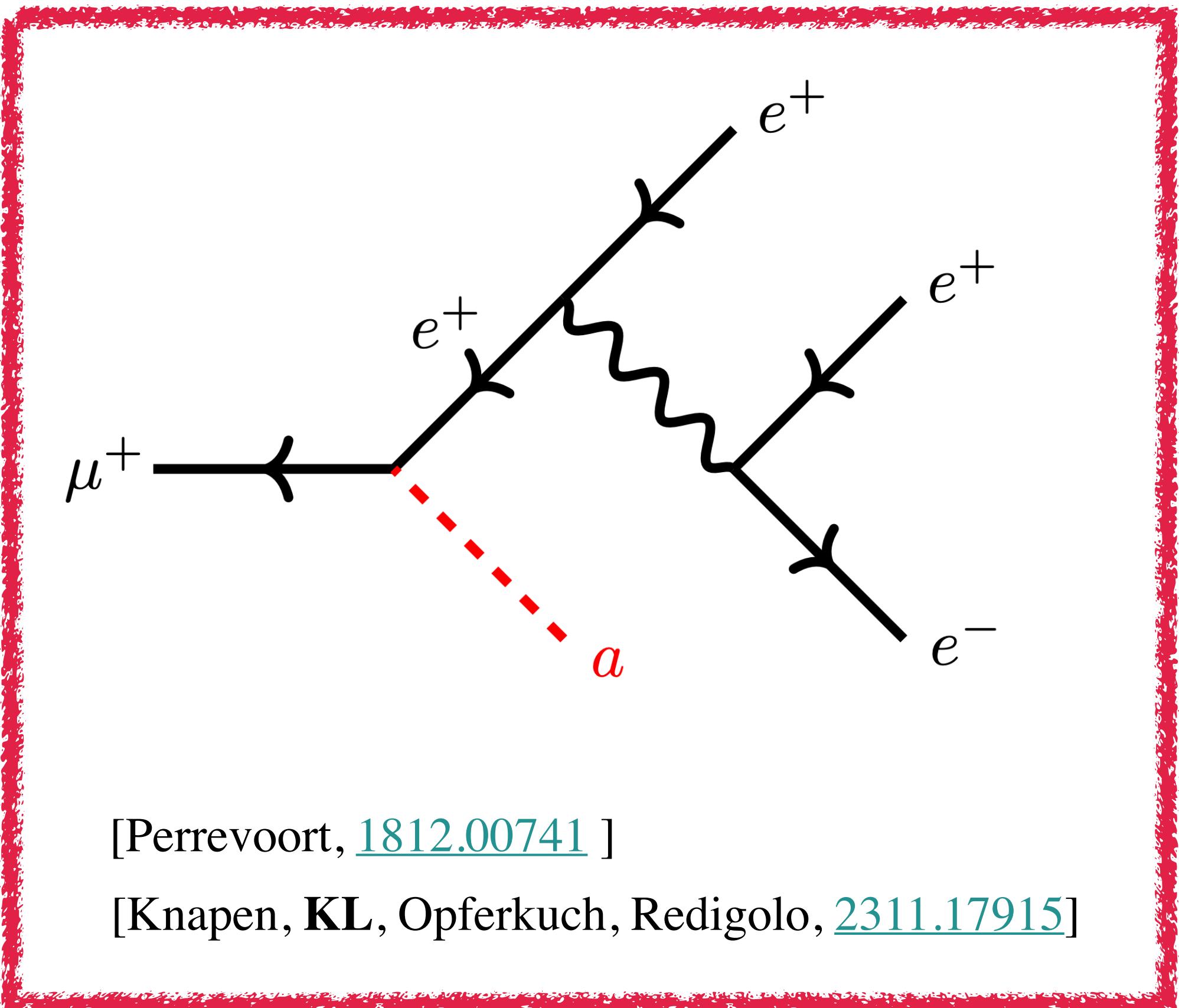


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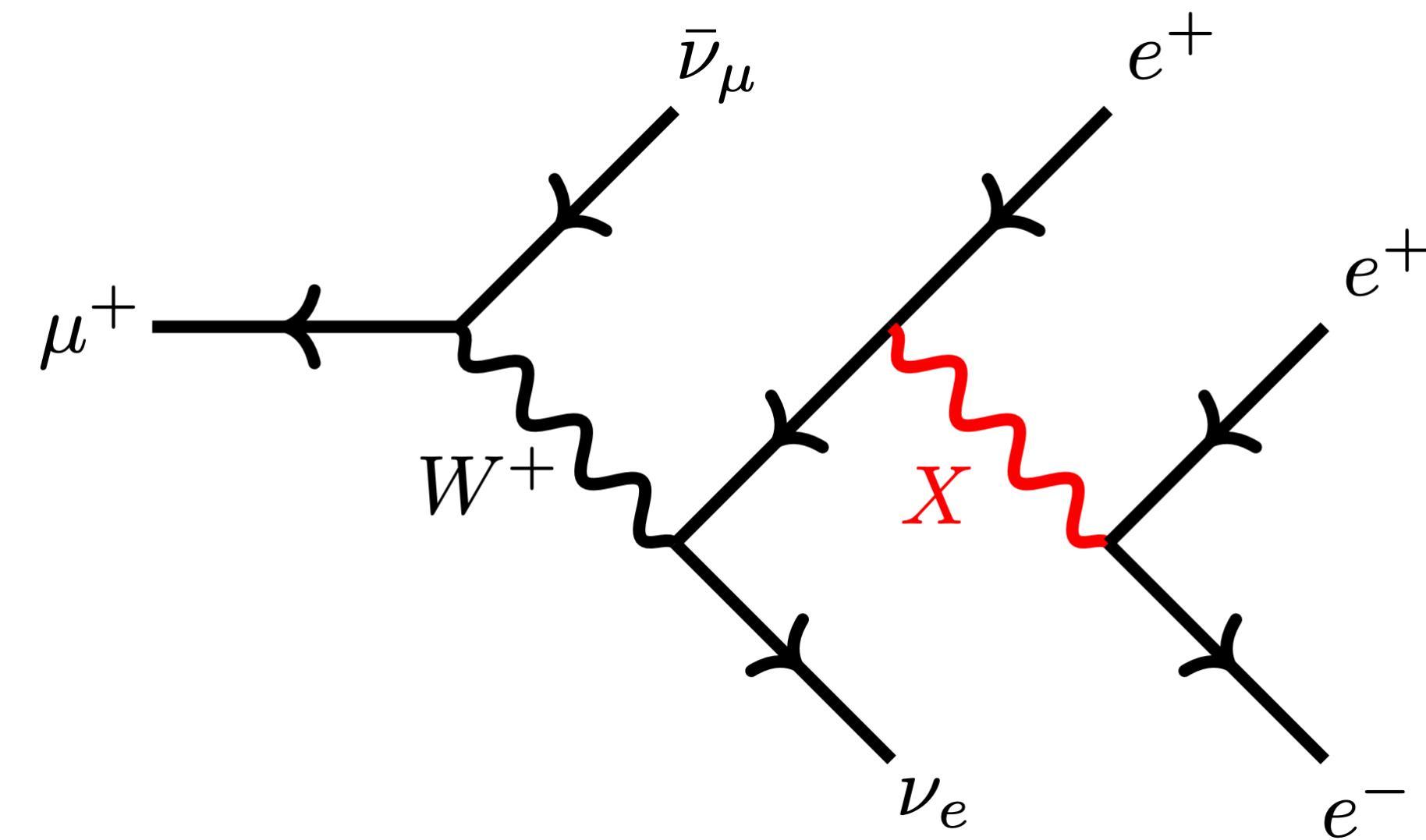
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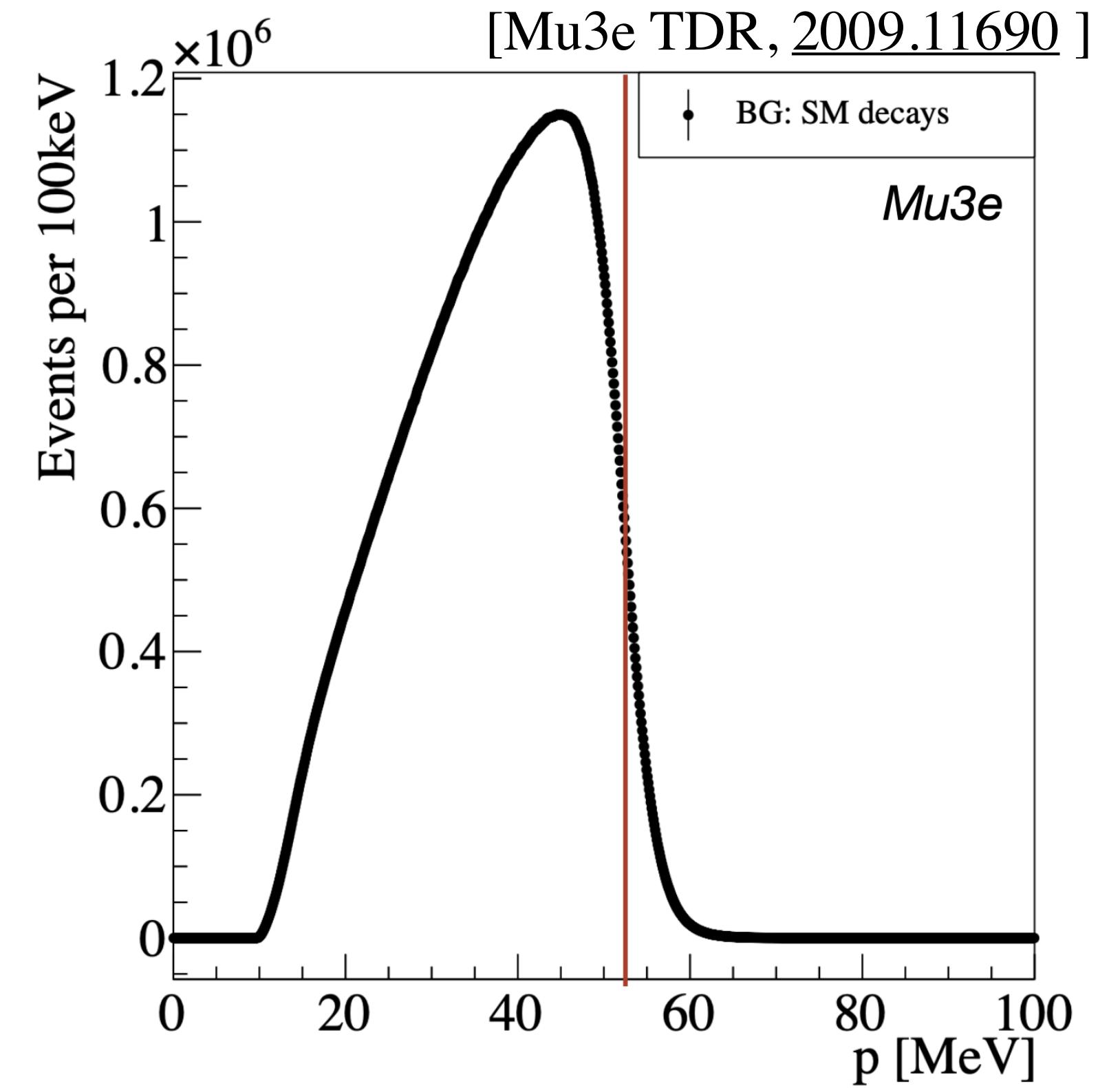
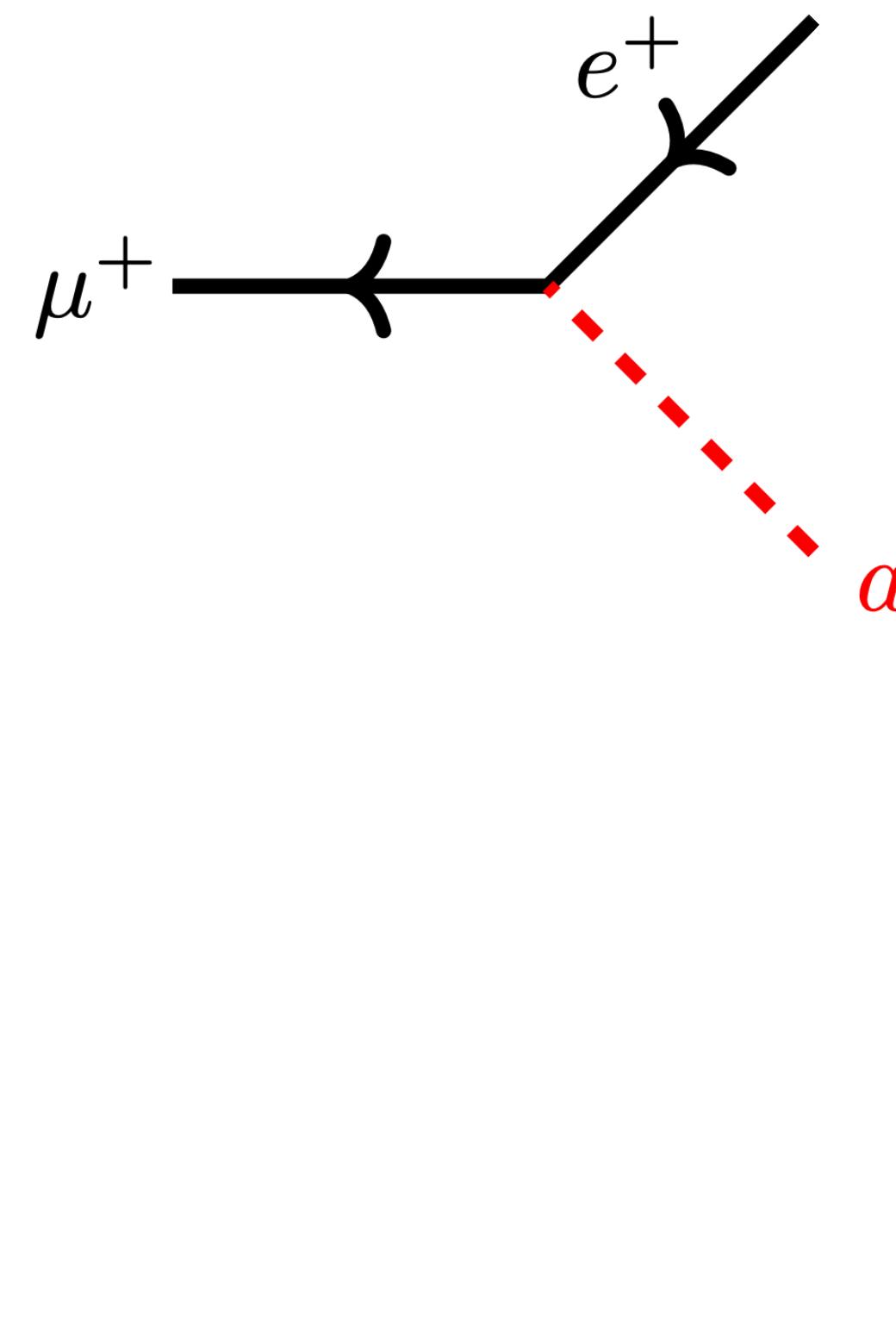
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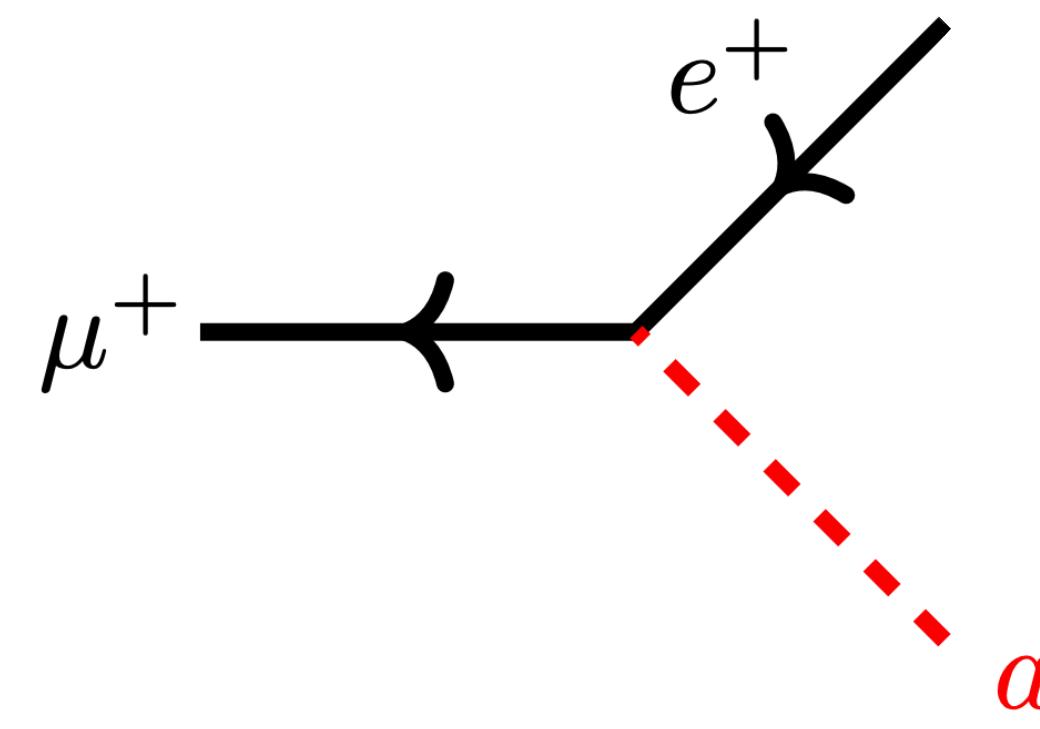
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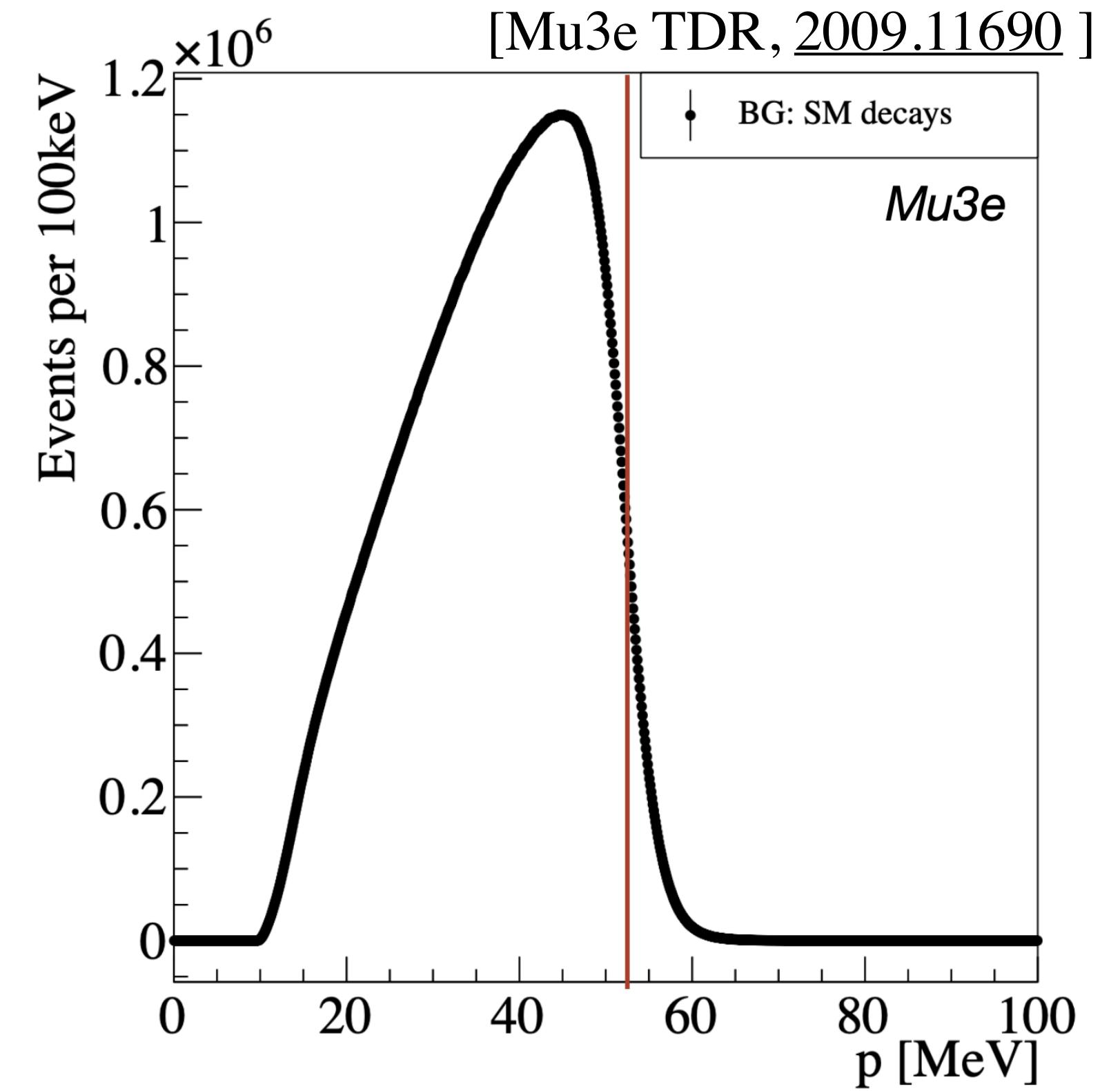
# Simplest Signature of CLFV Axions



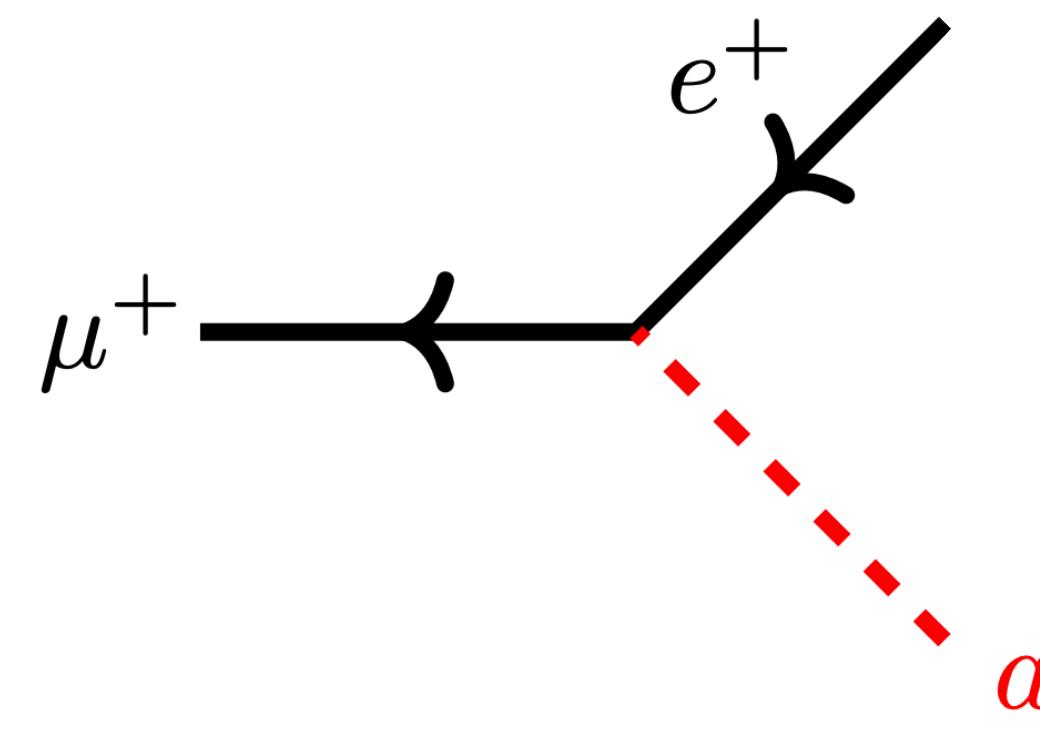
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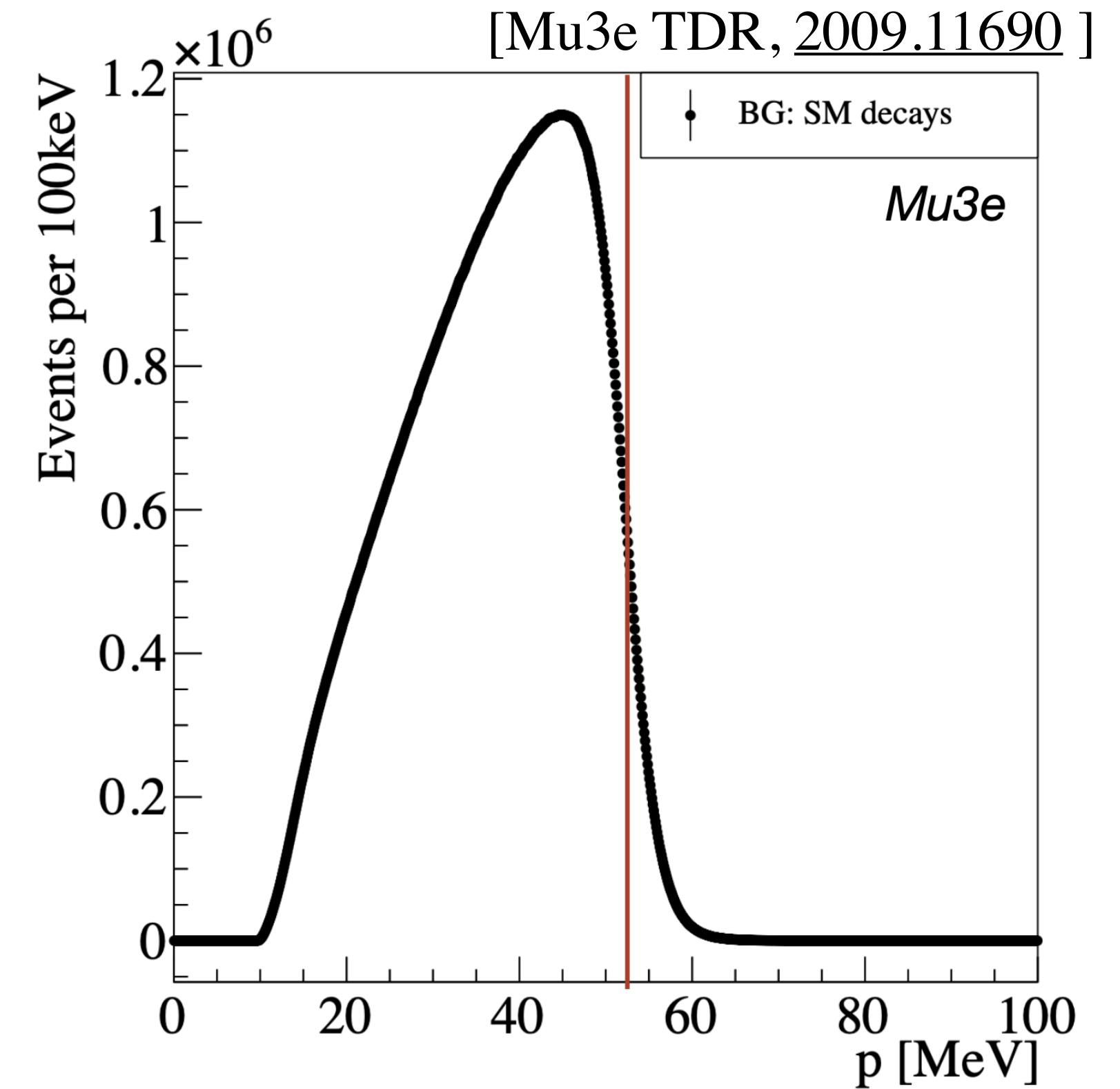


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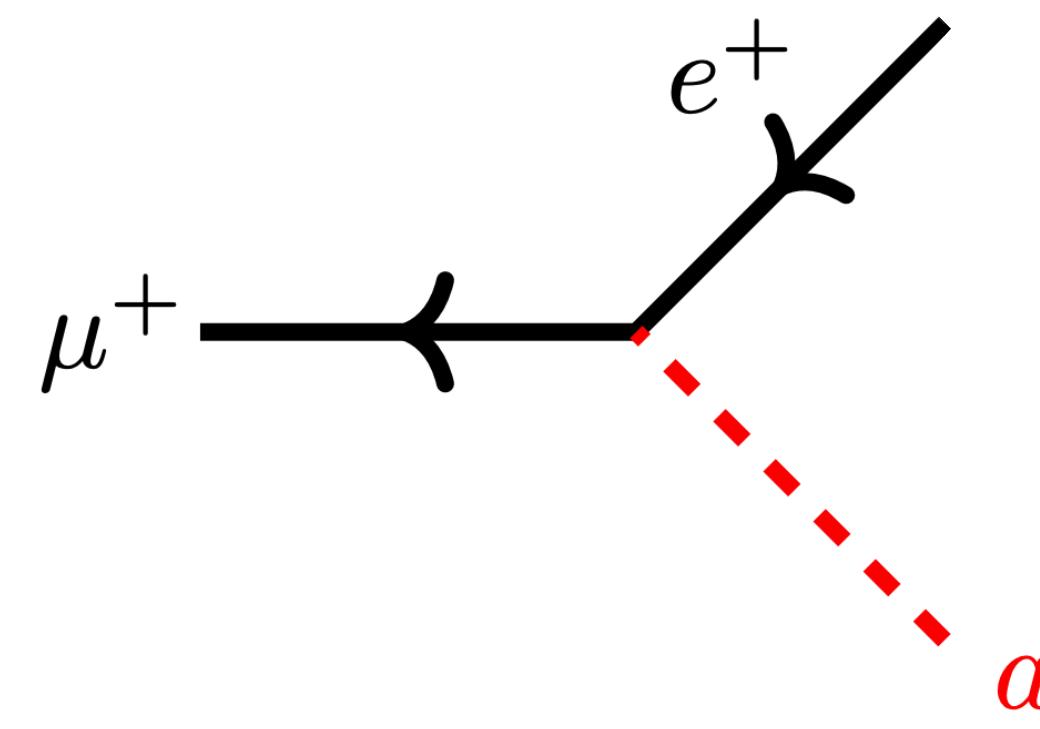


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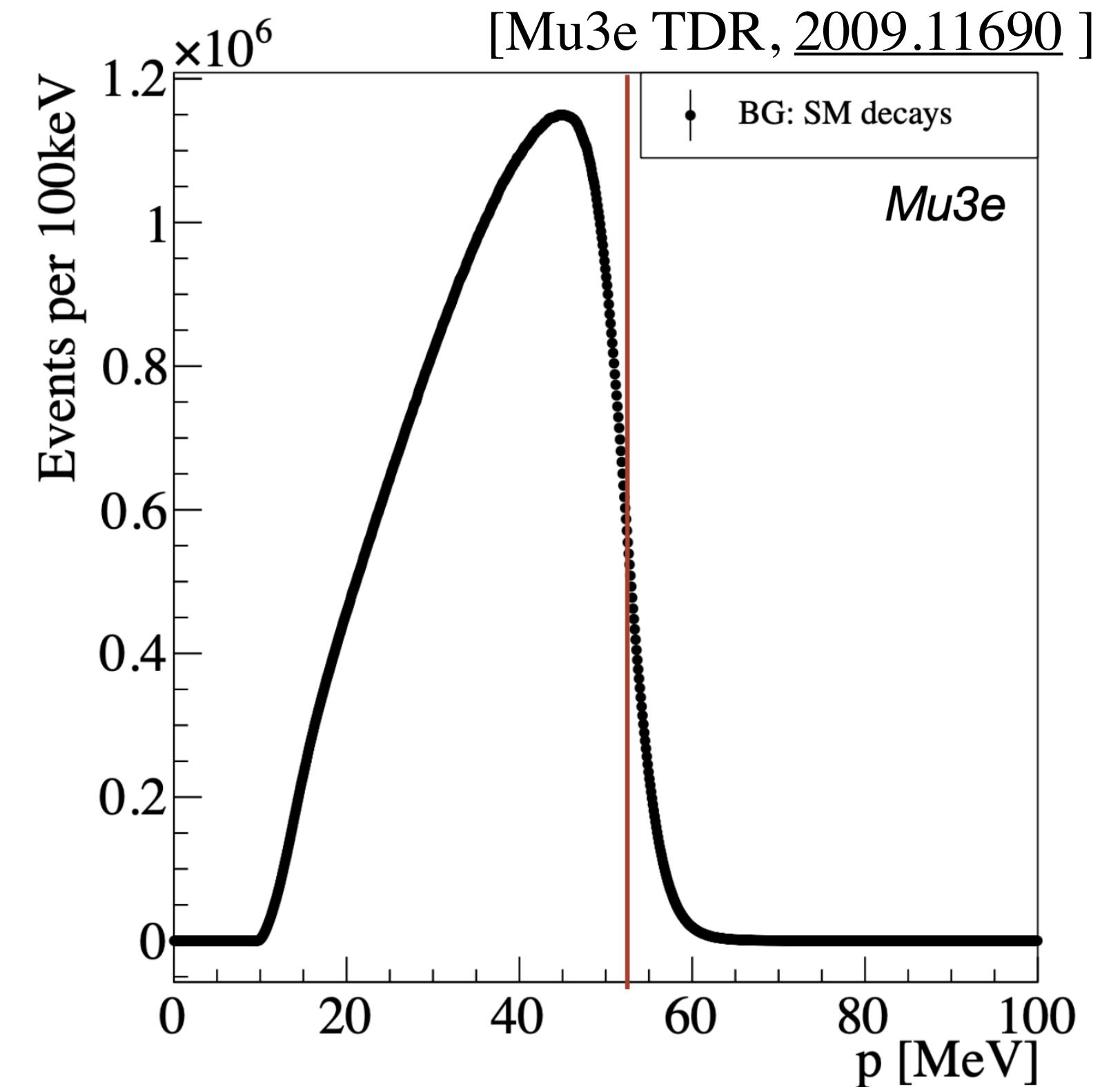


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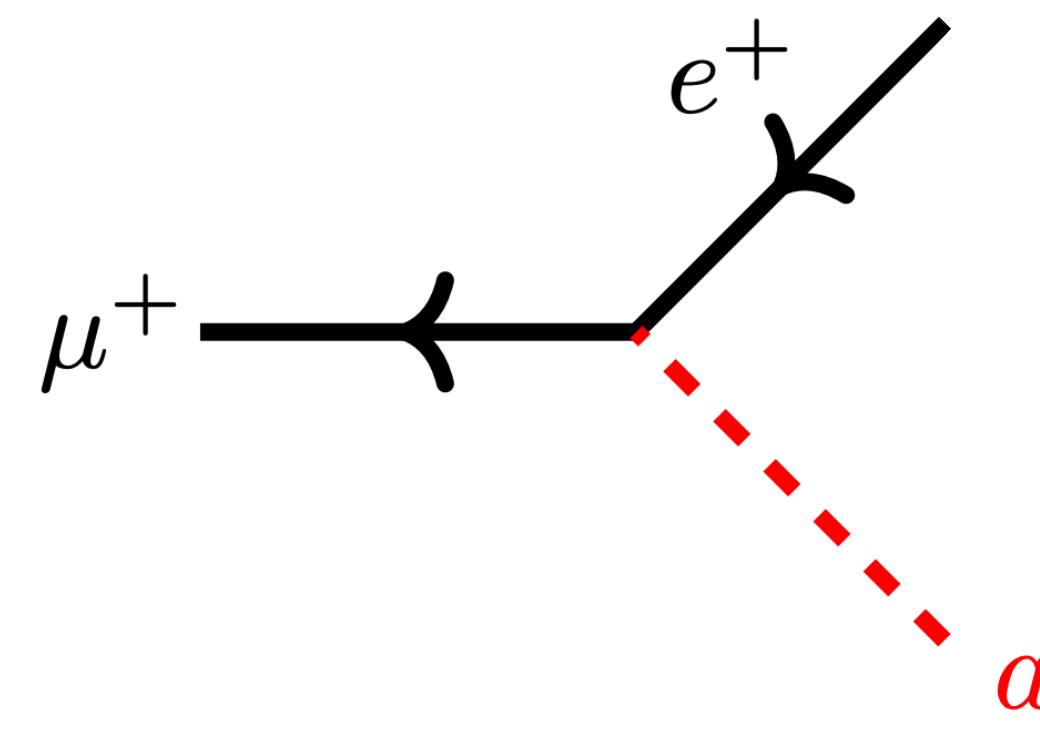


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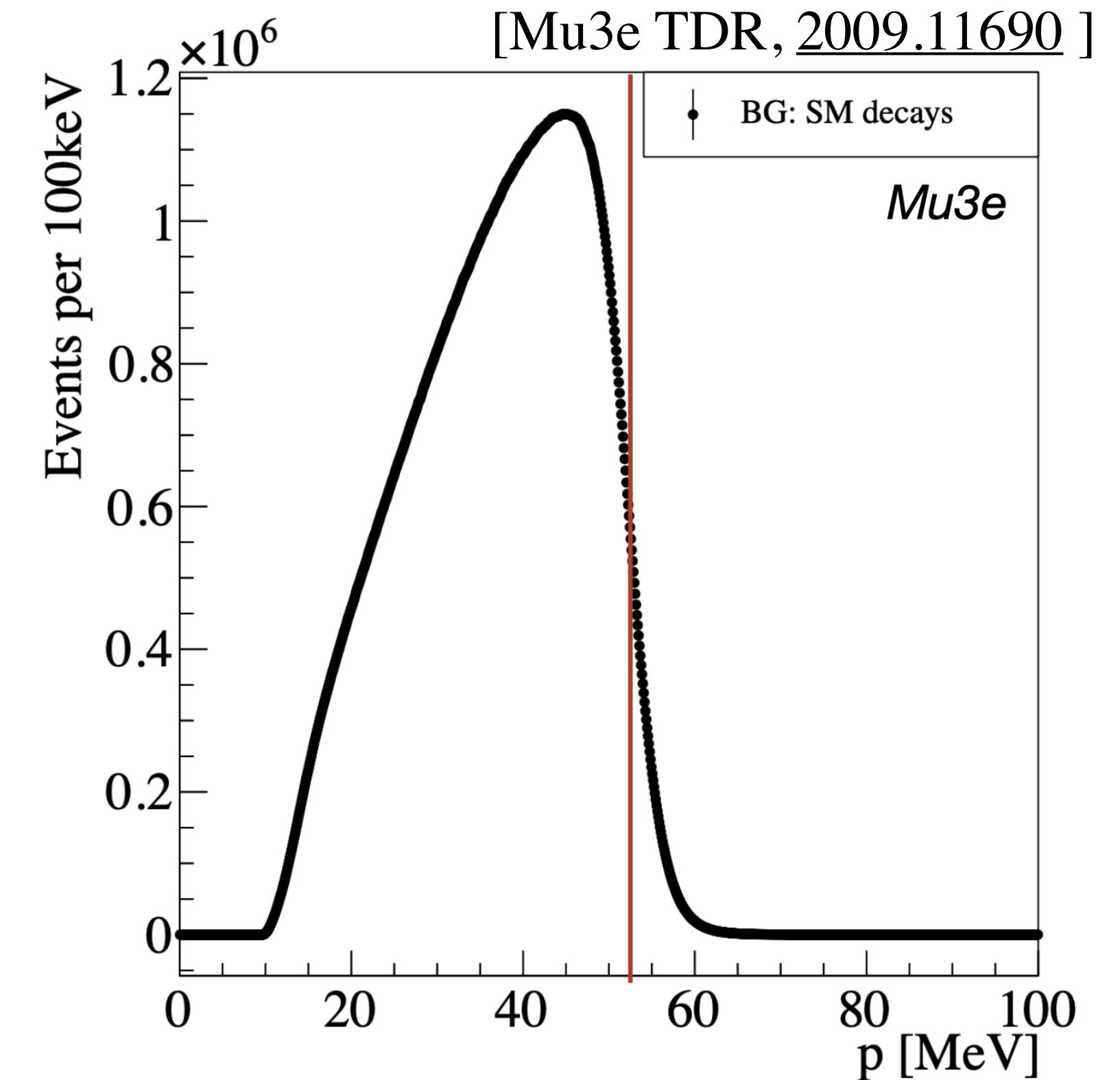


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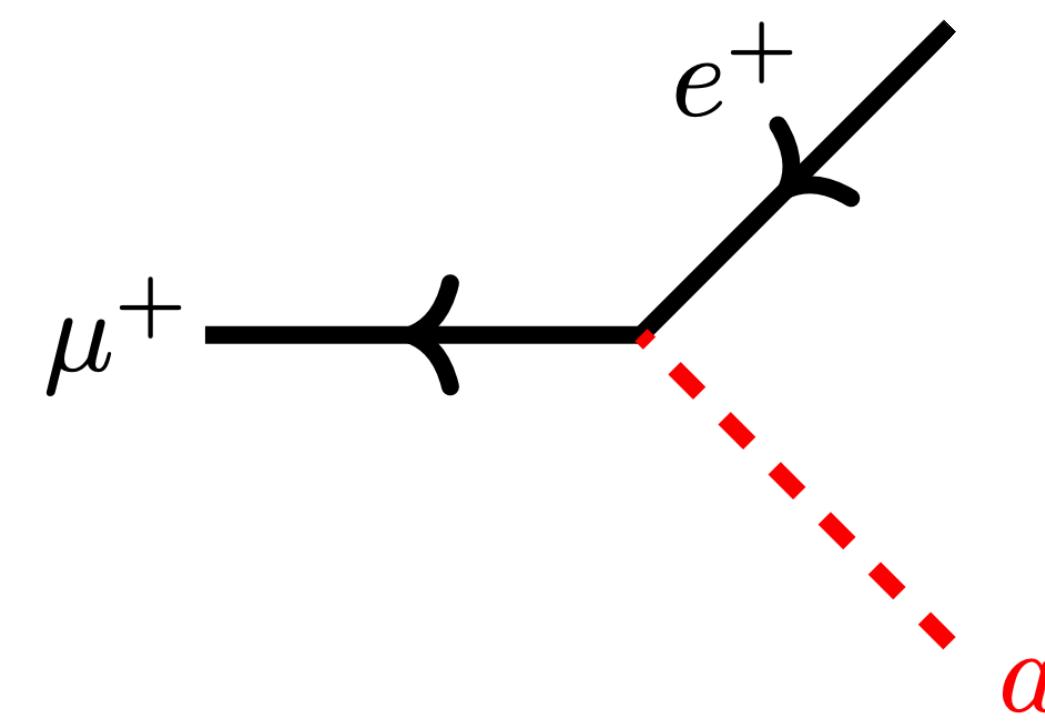


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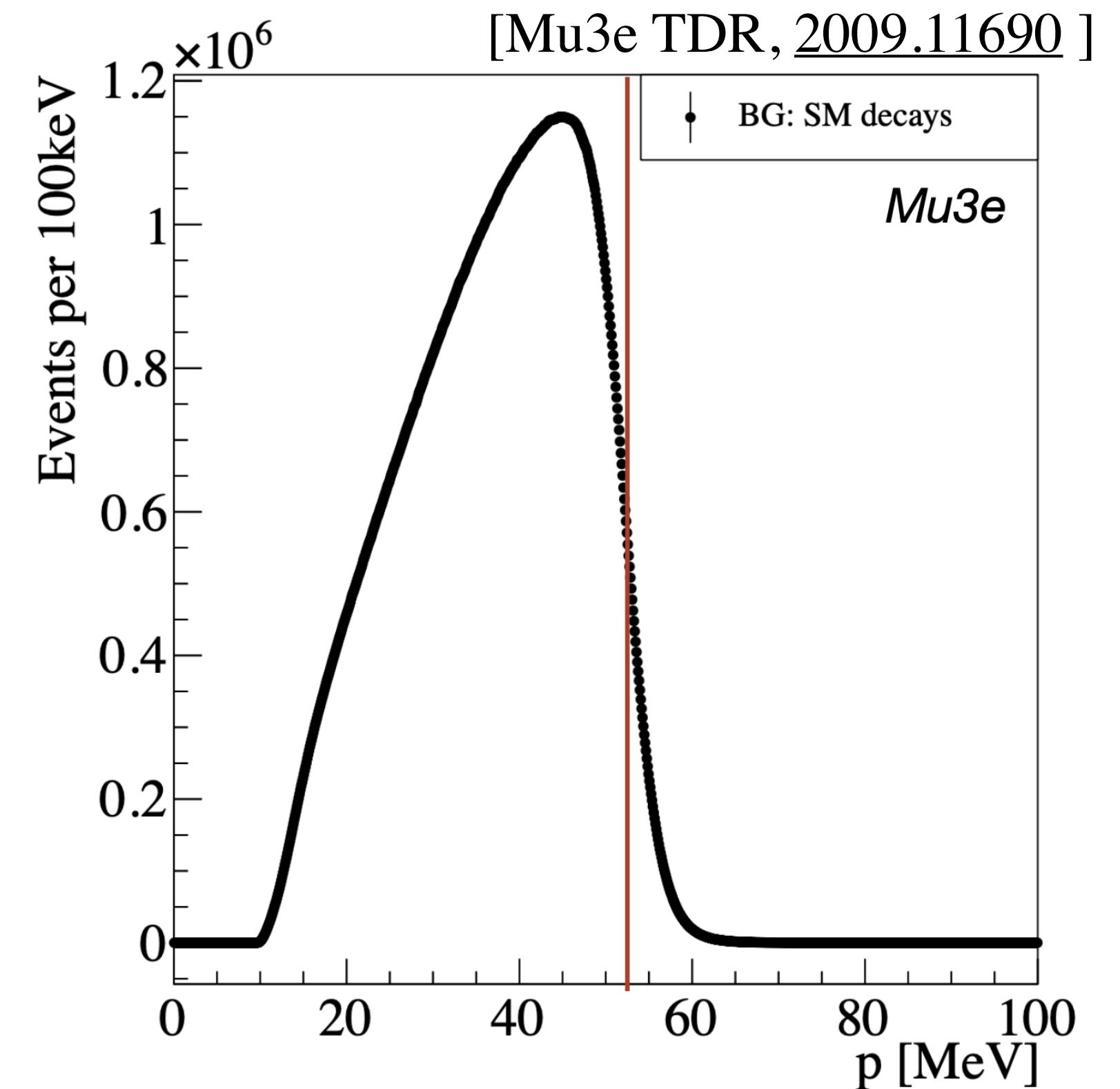
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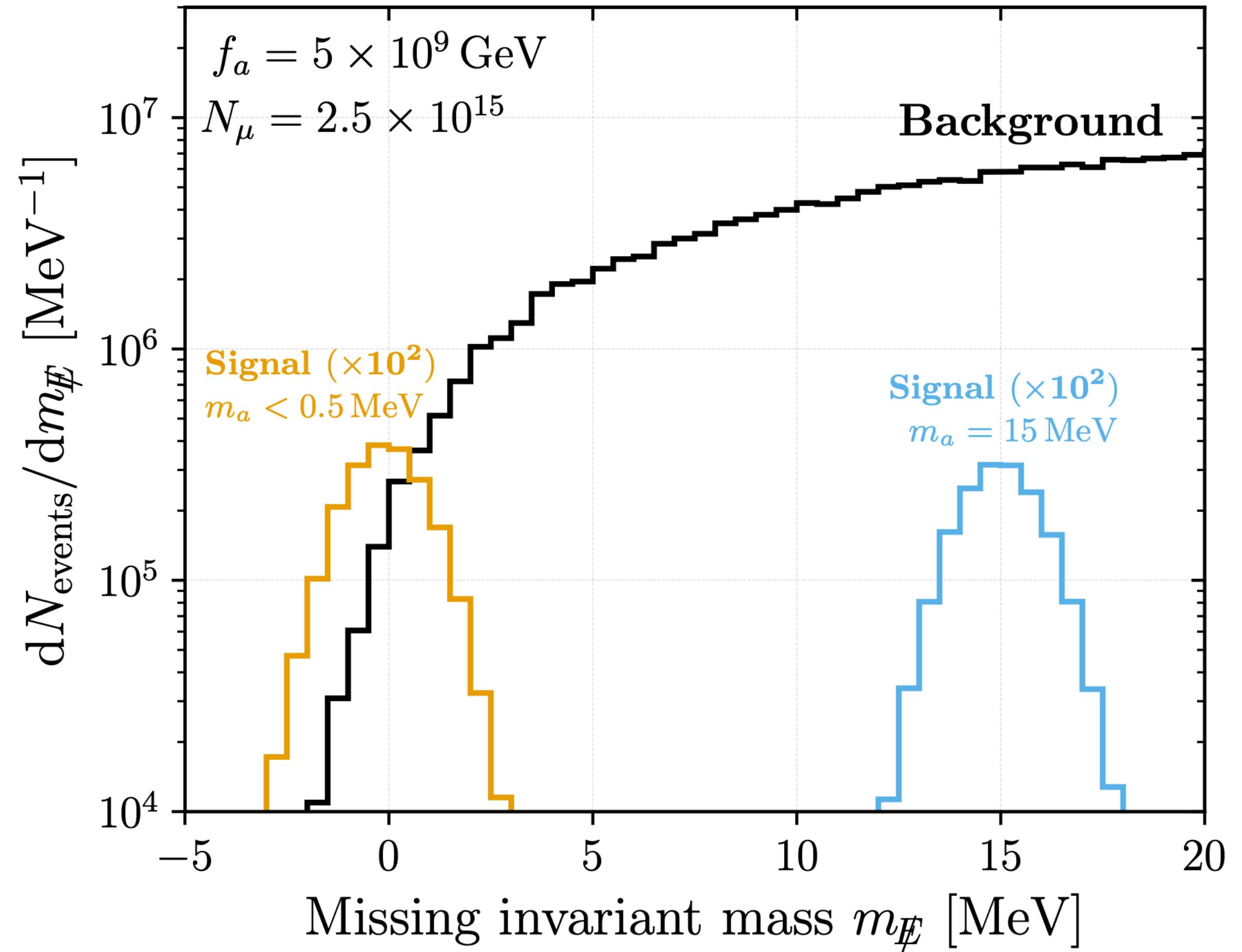
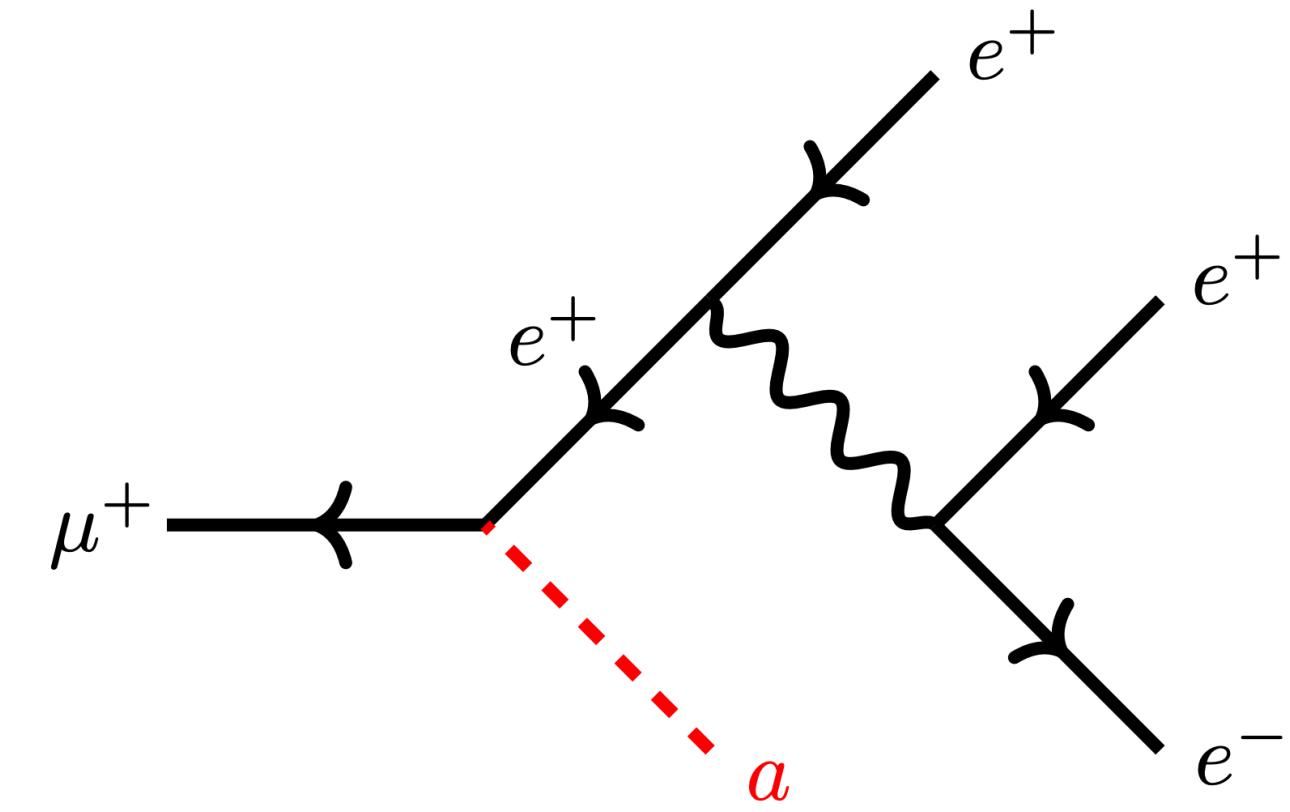
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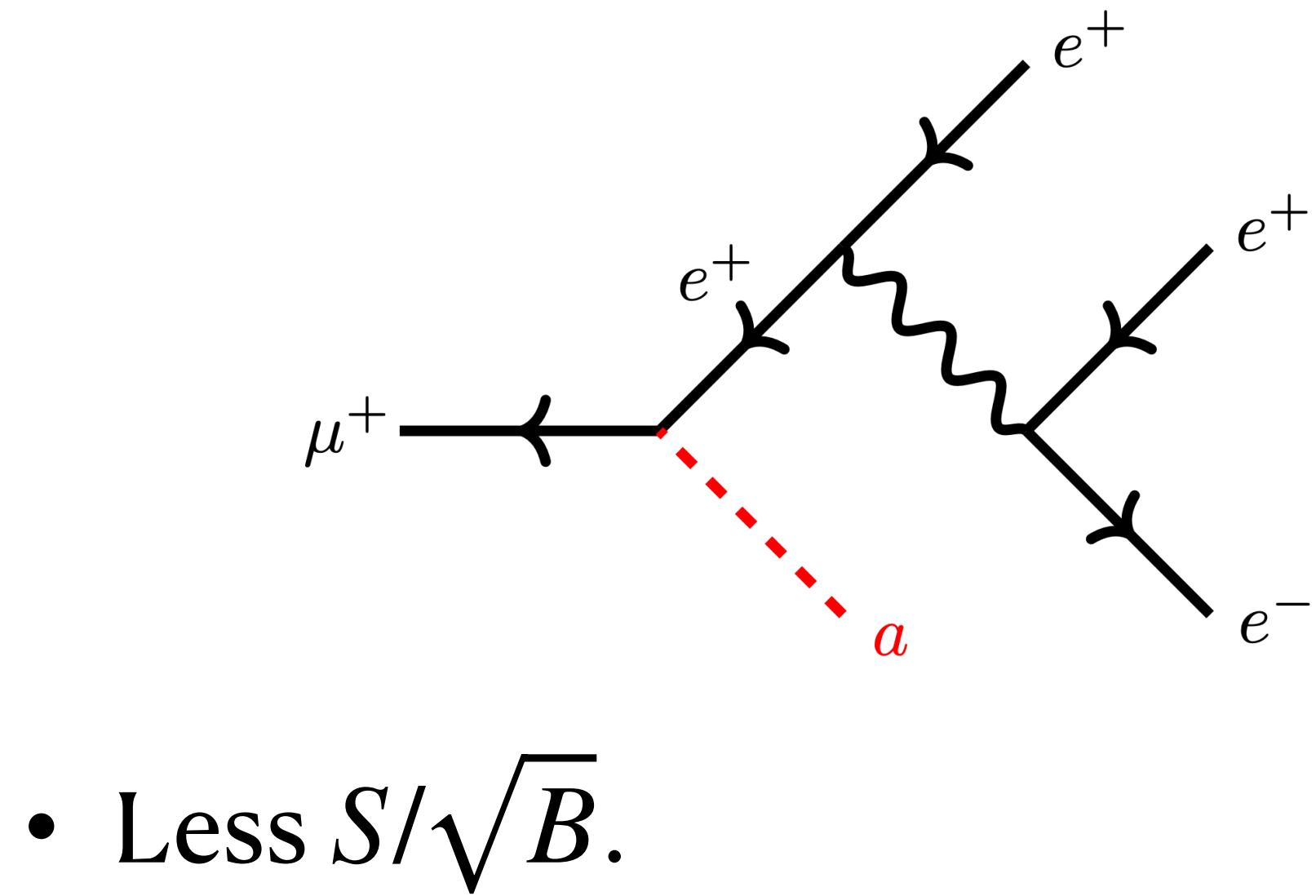
⇒ It is worth exploring alternatives.



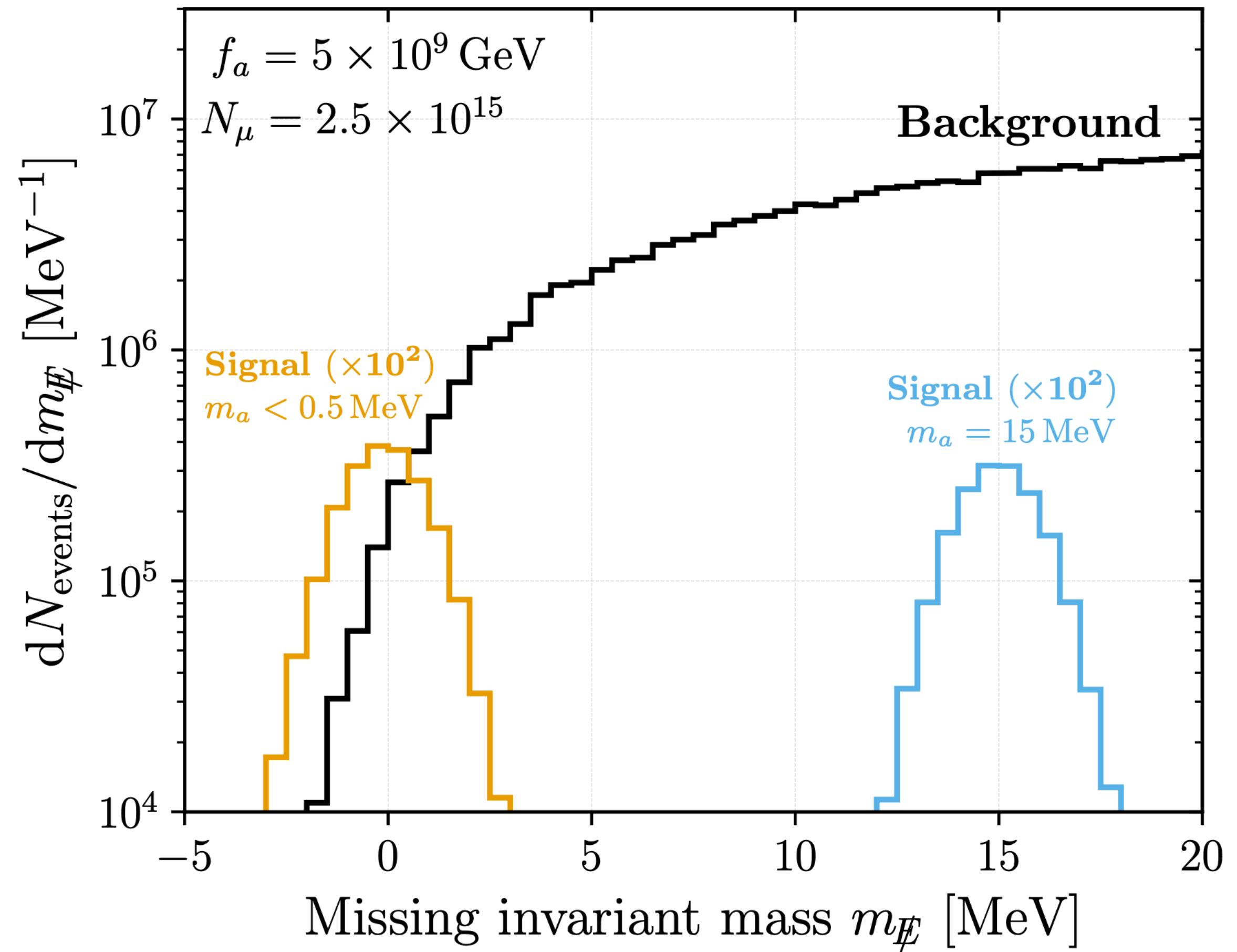
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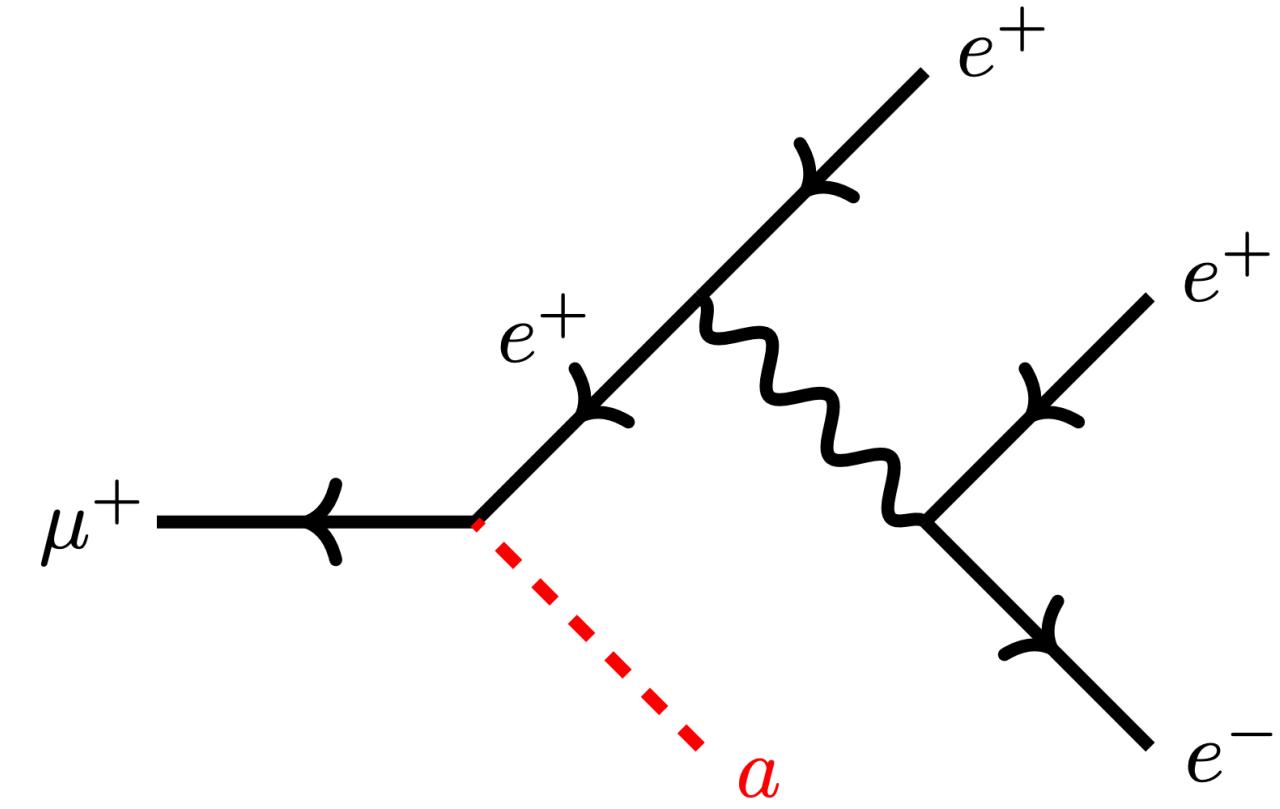
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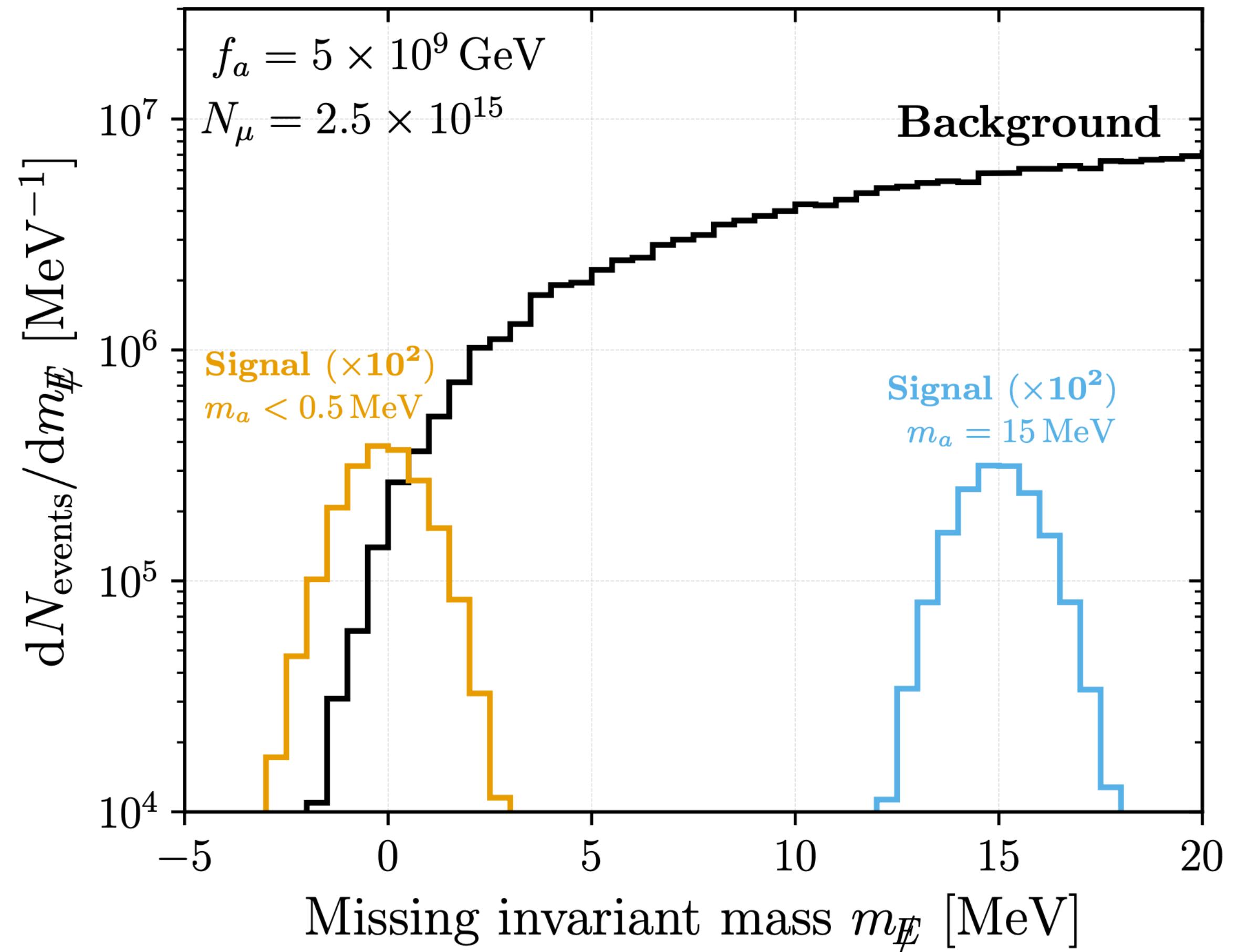
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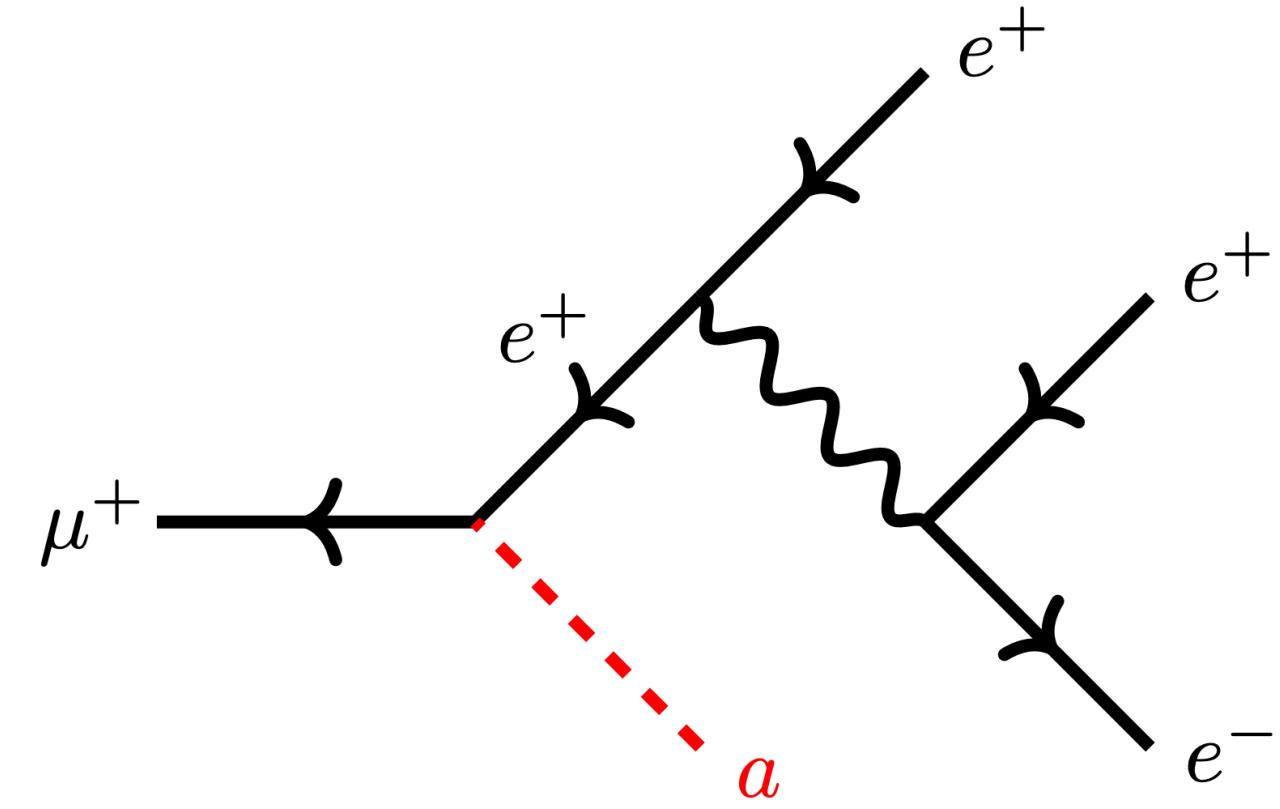
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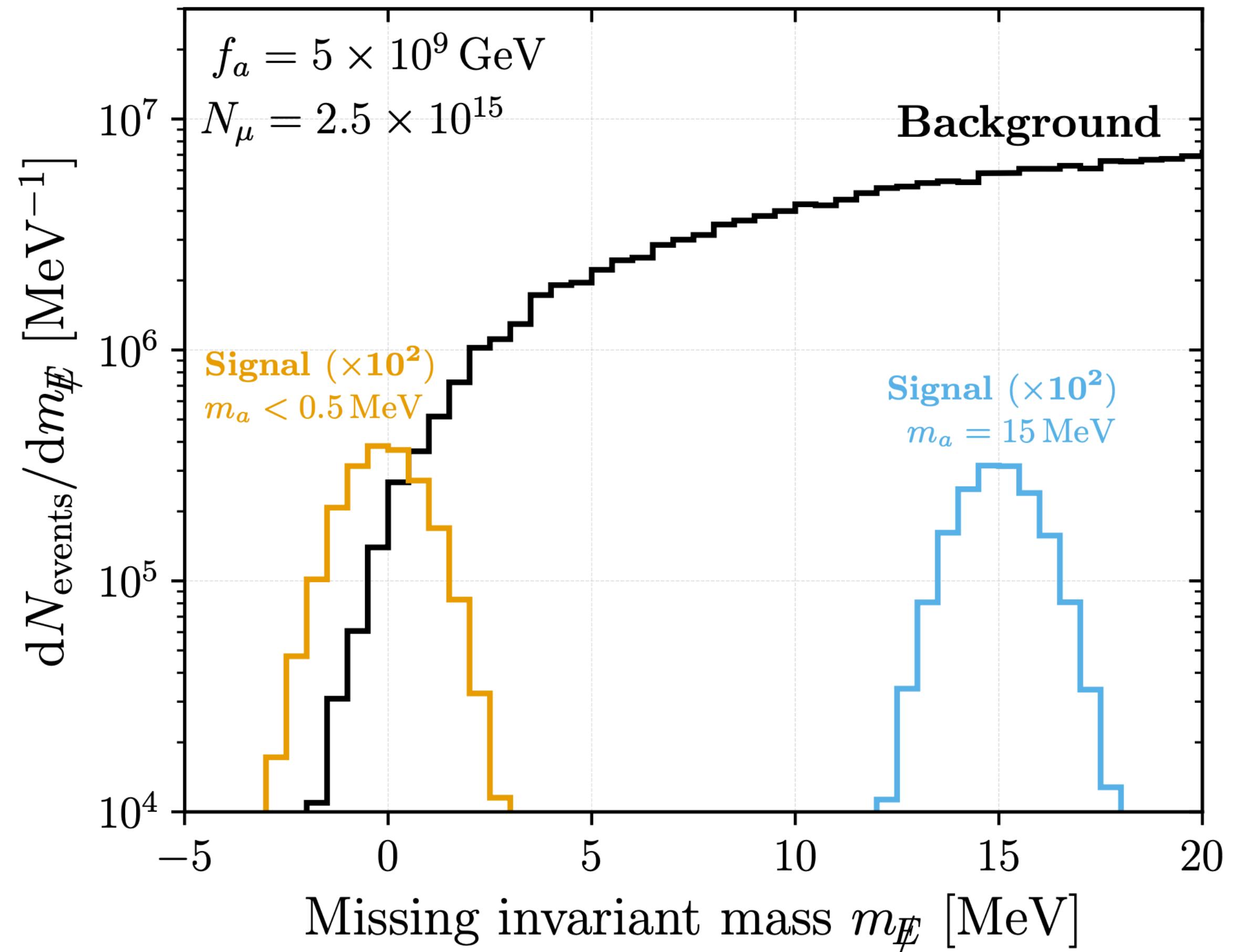
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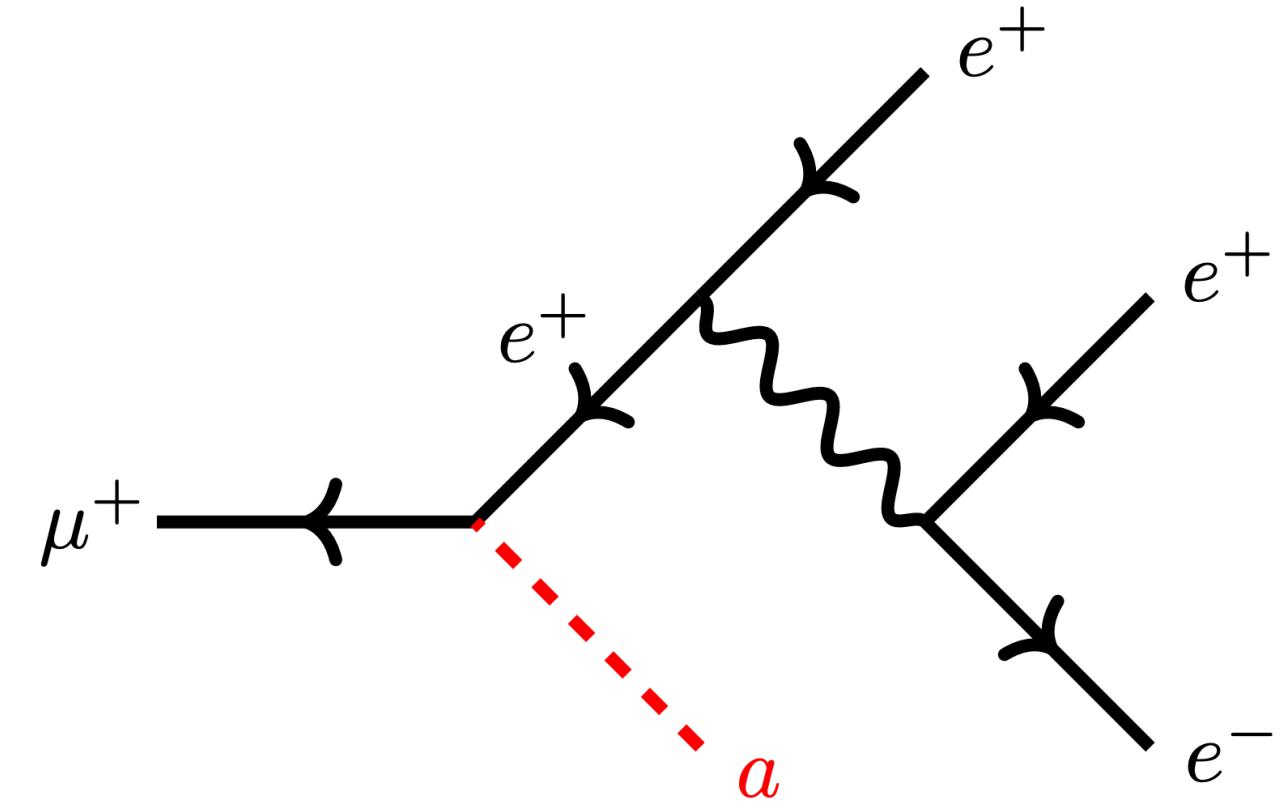
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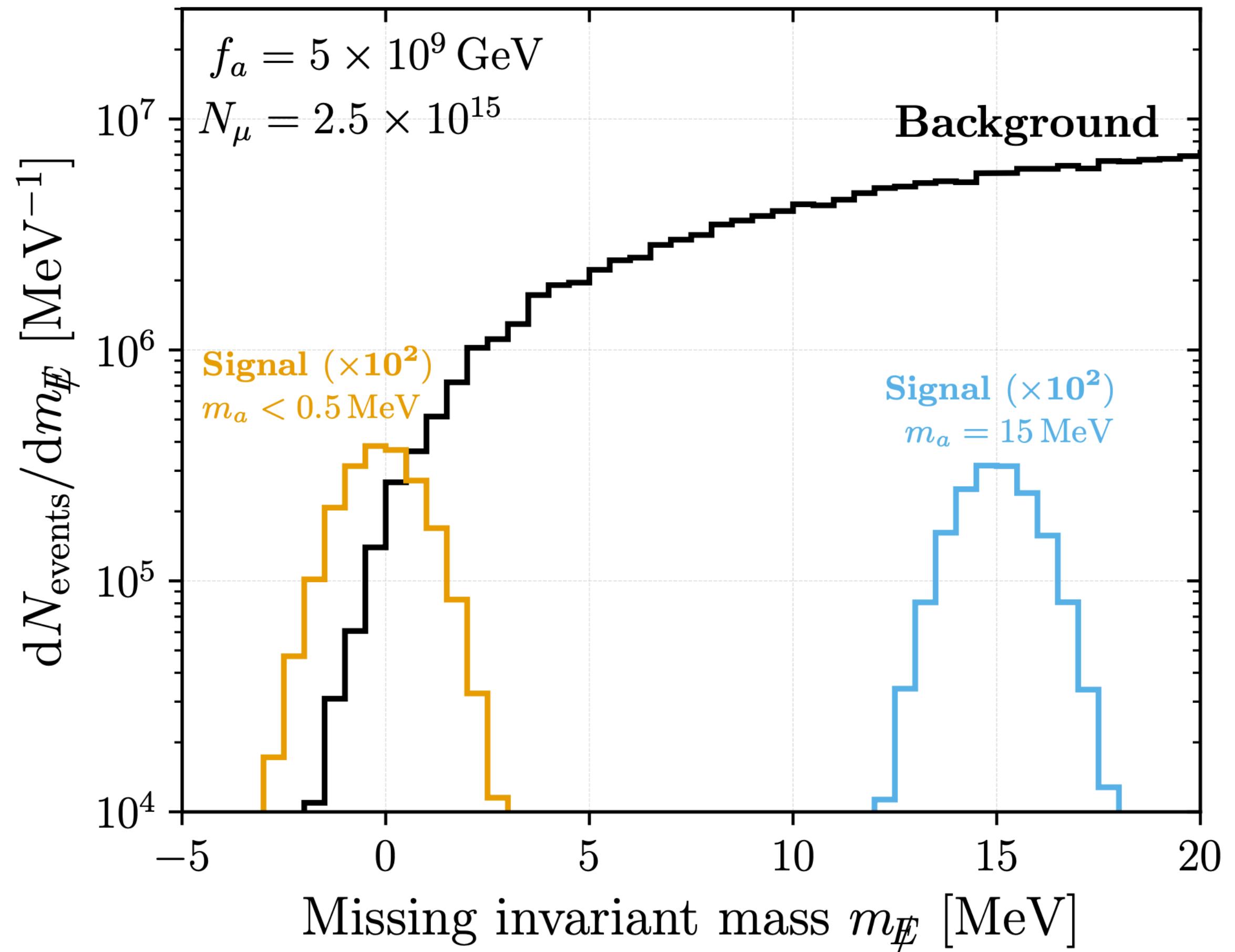
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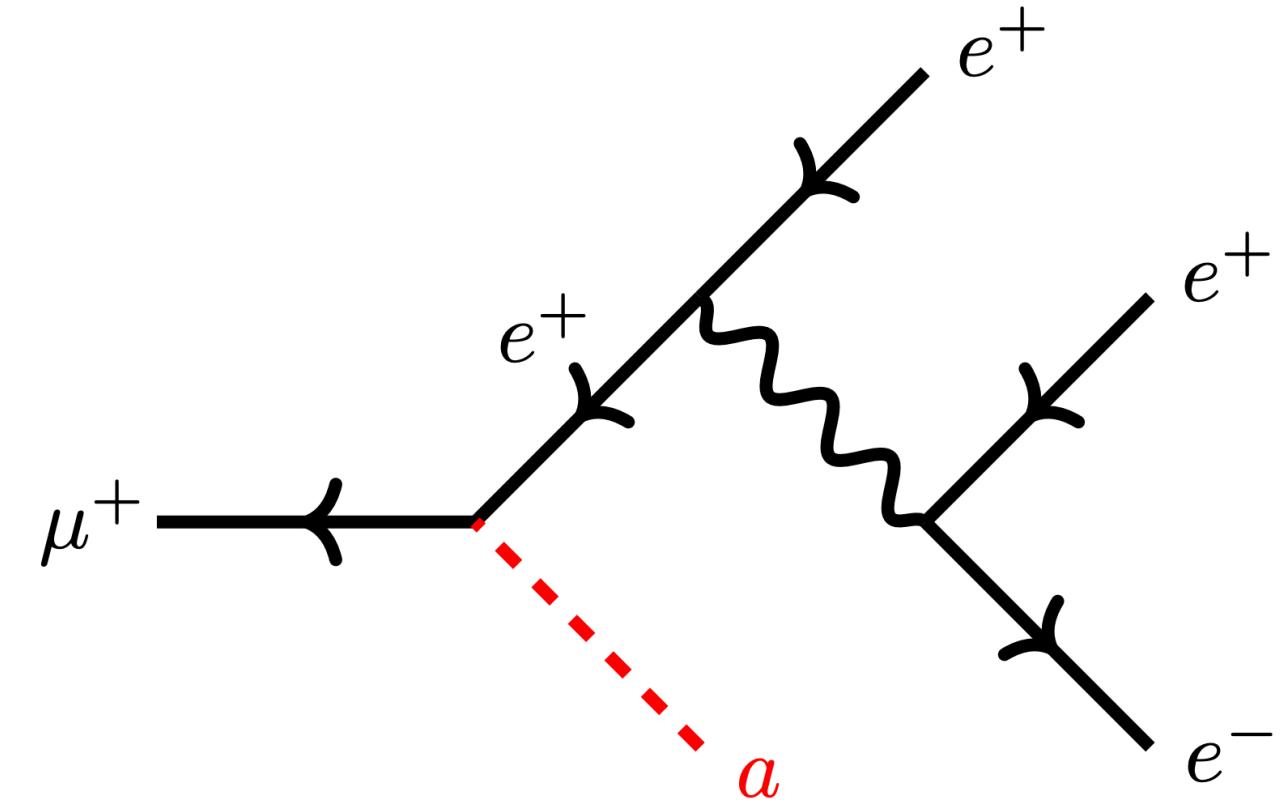
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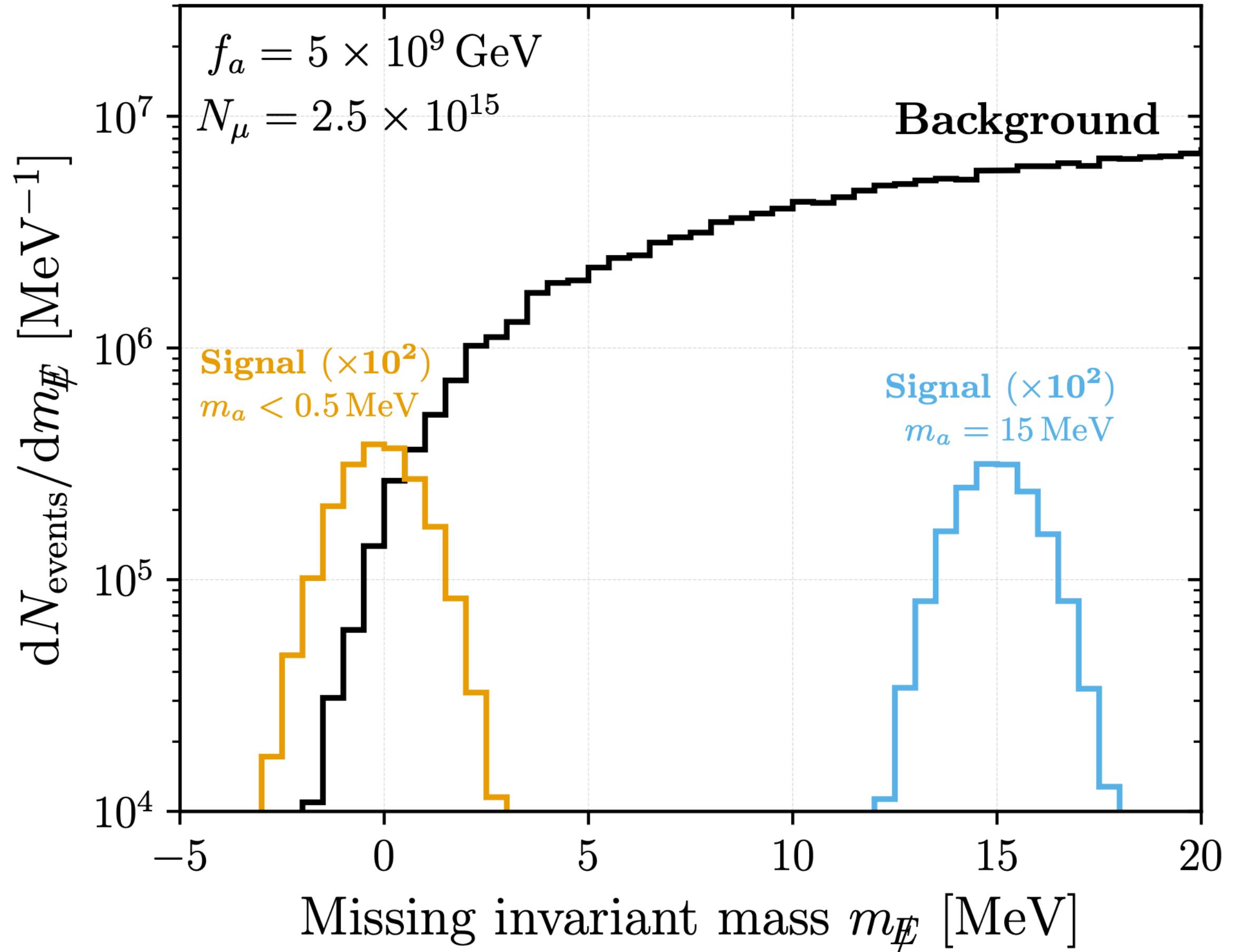


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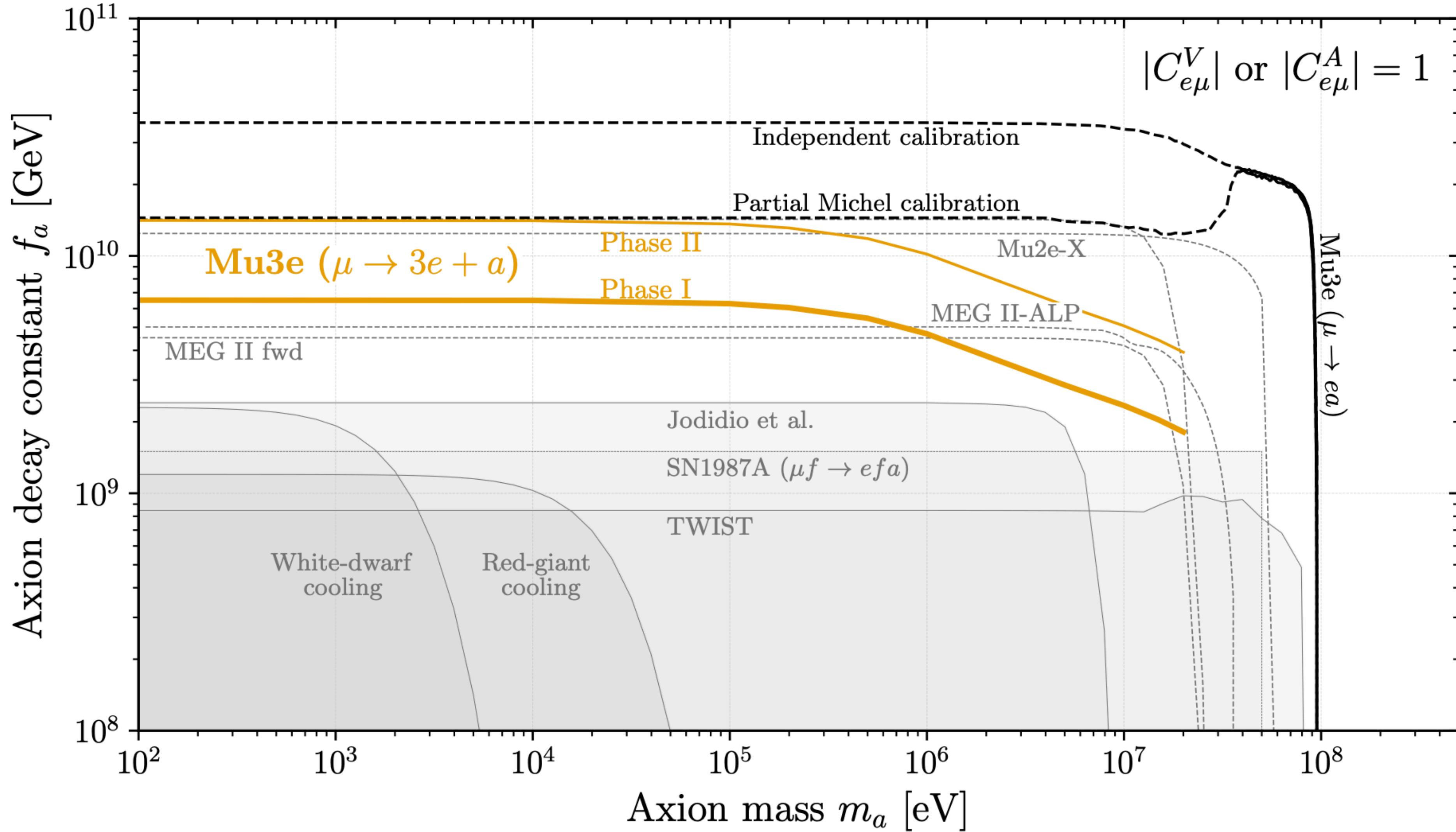


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⇒ Less statistics, but also less systematics.

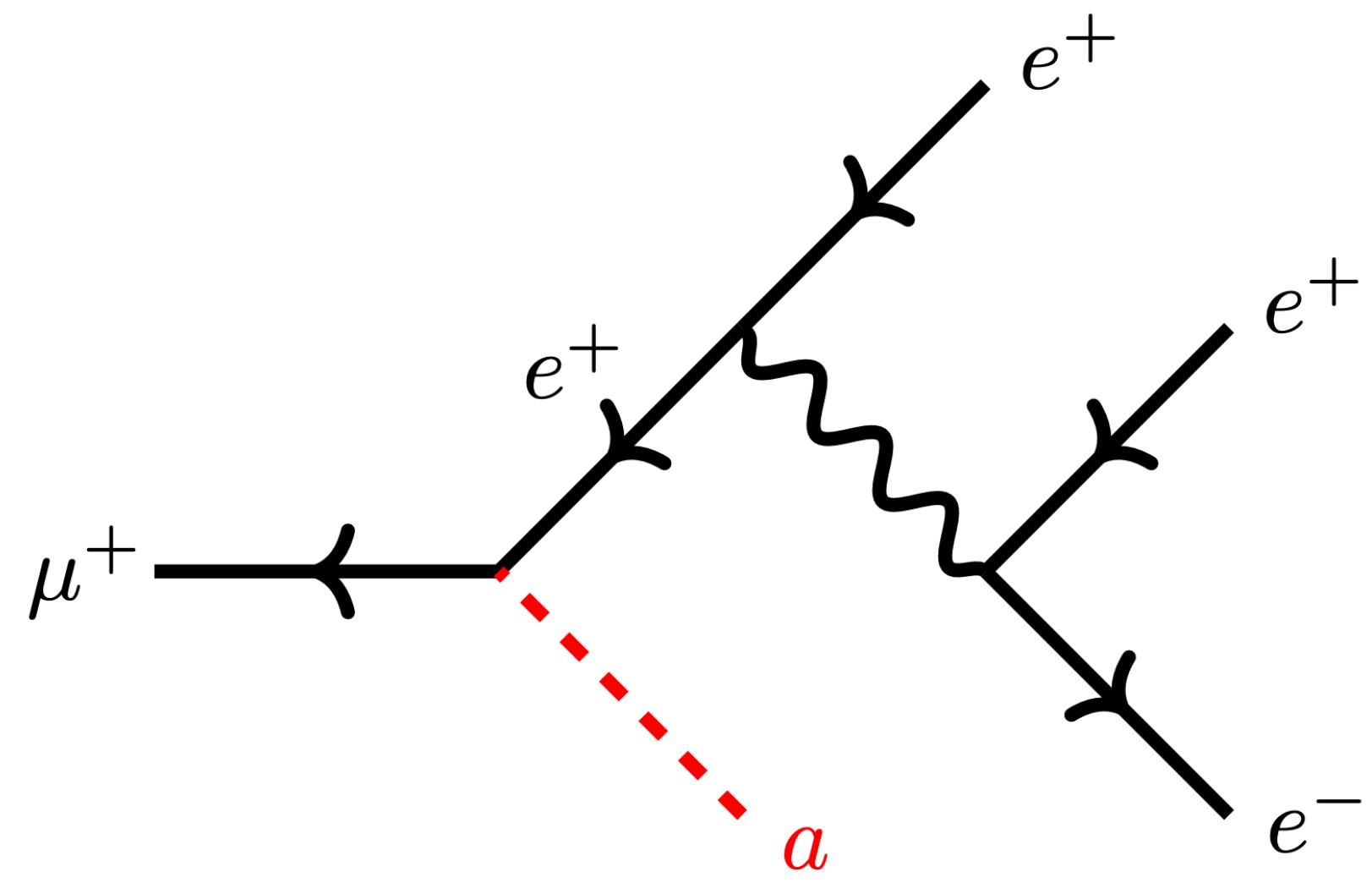


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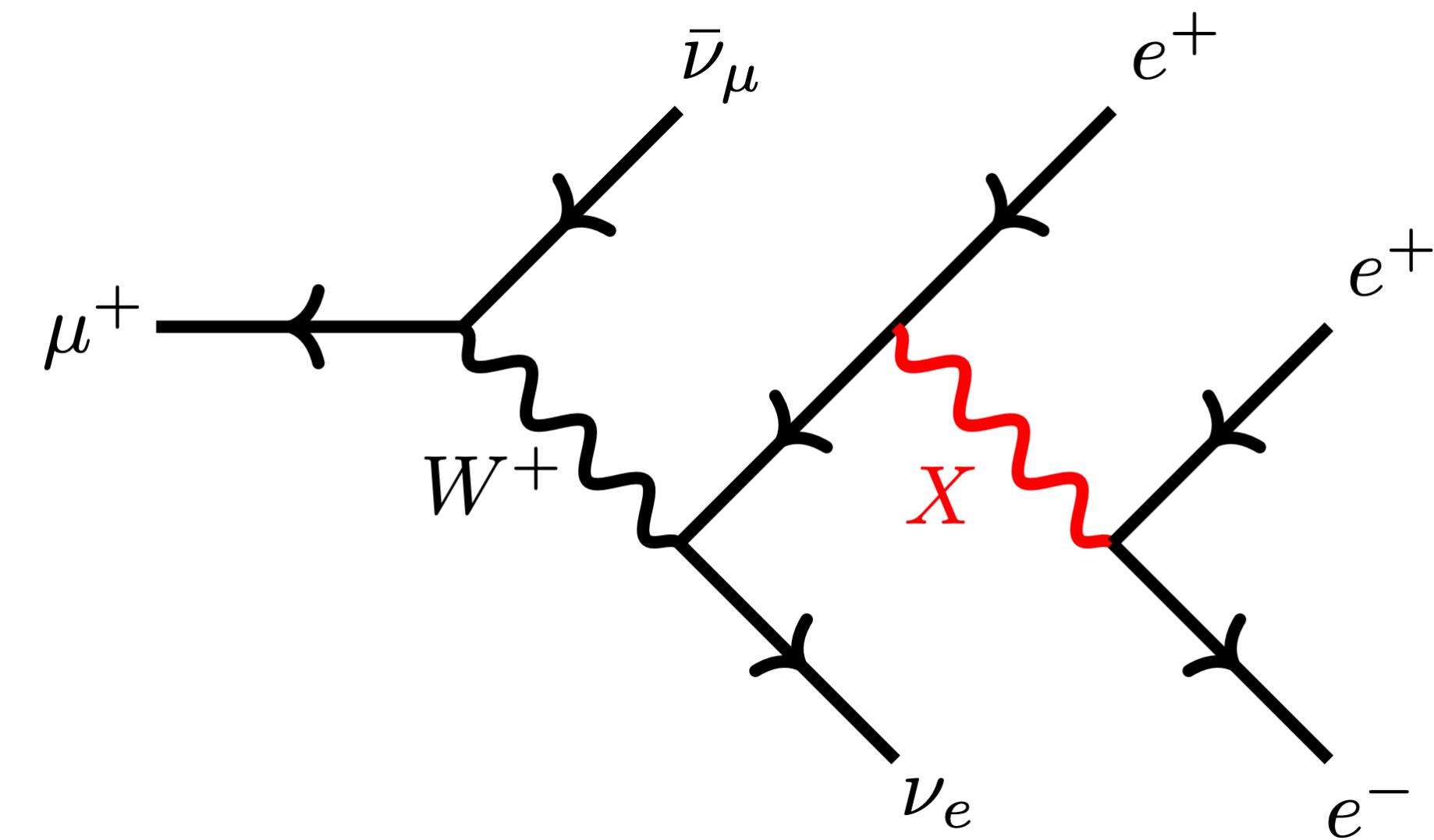
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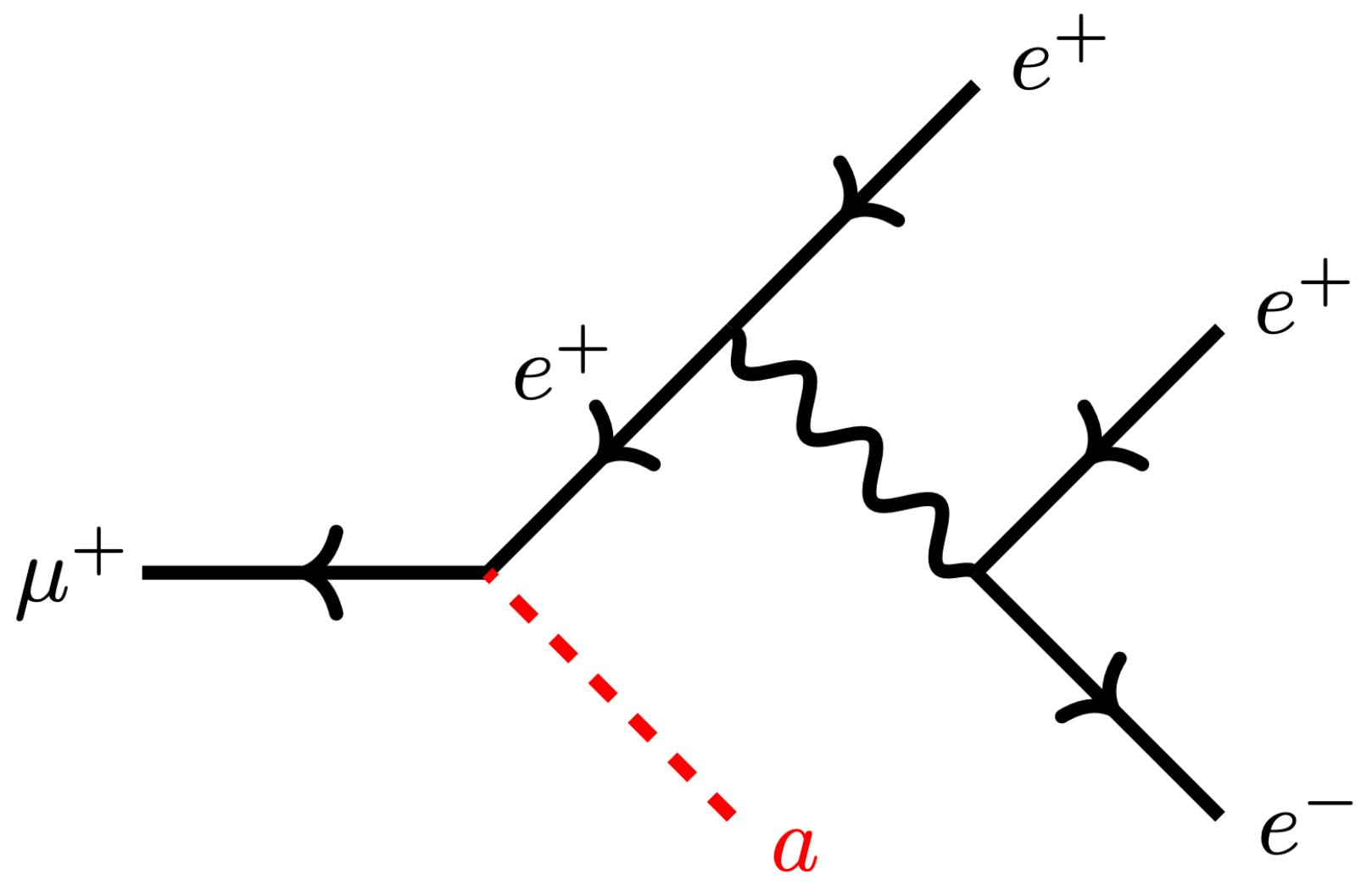


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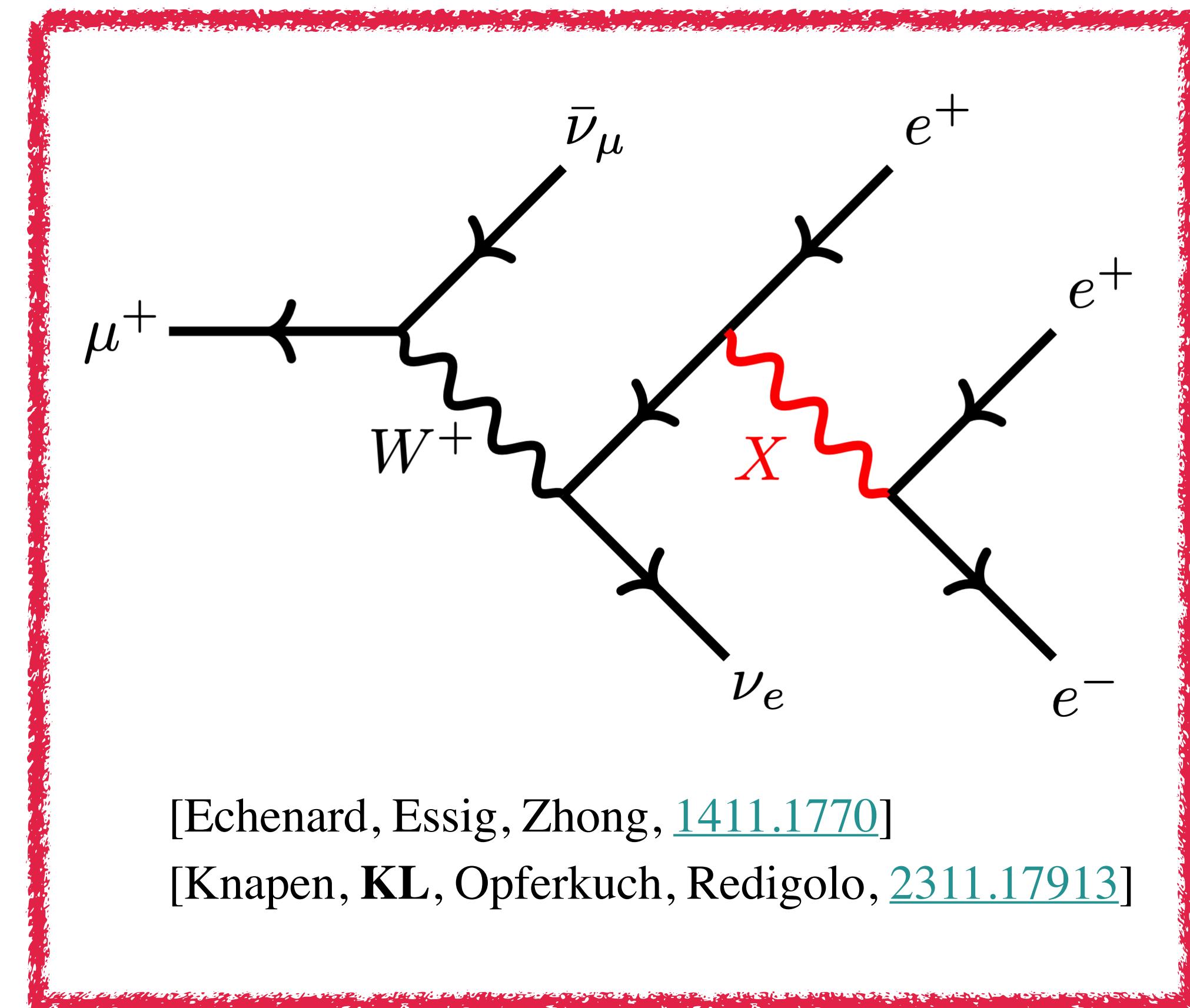
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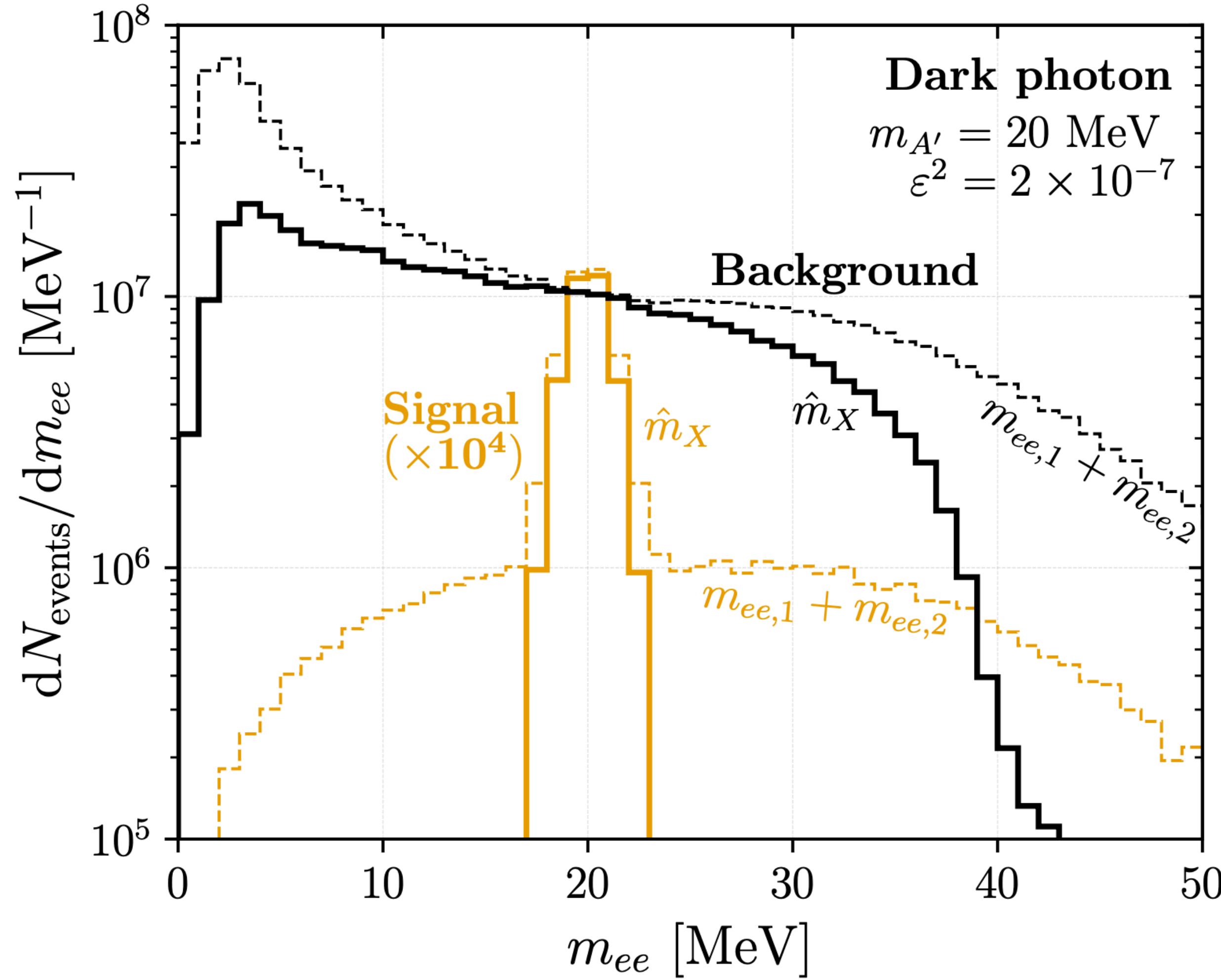
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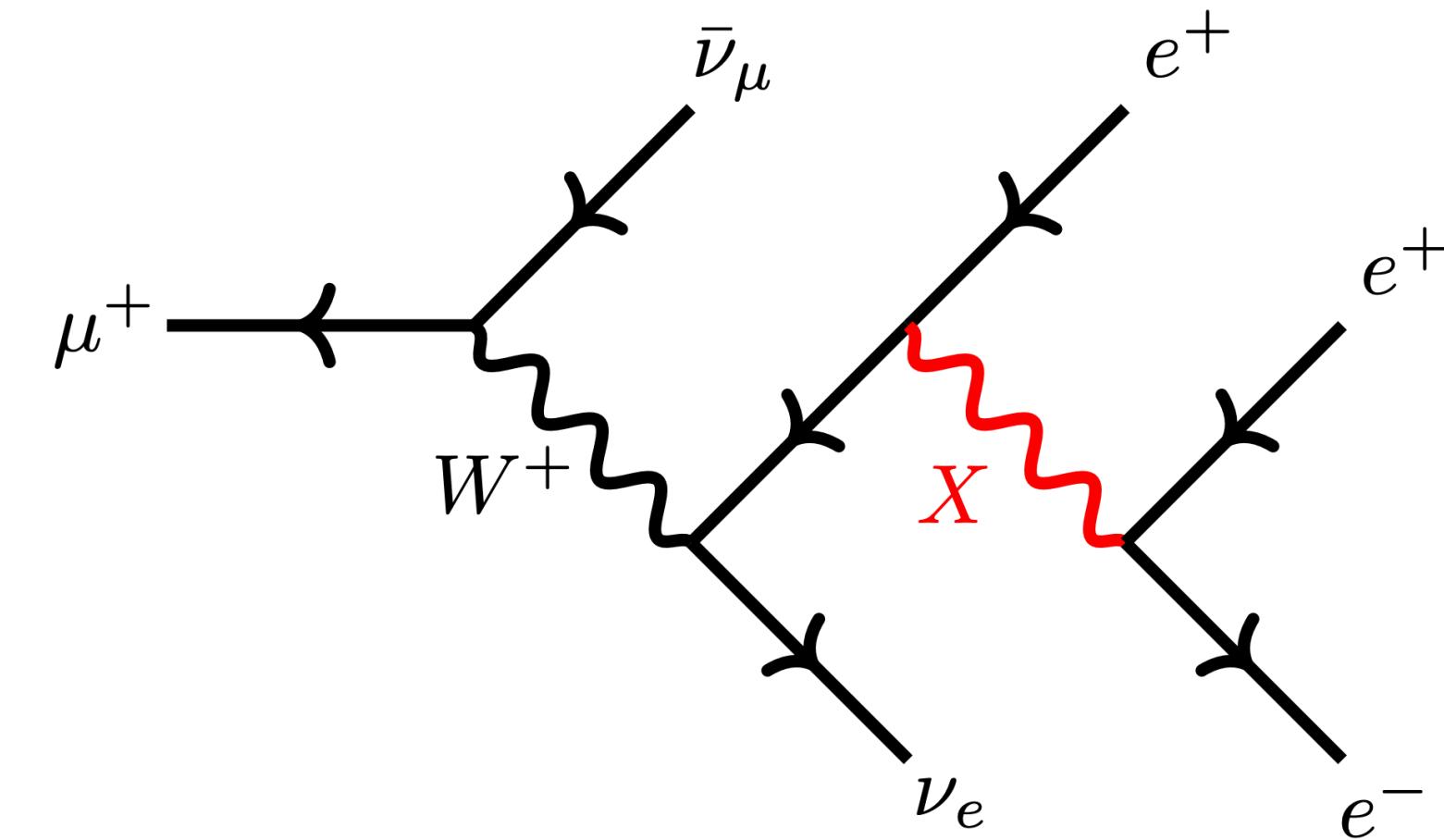
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# Resonance Search in Mu3e

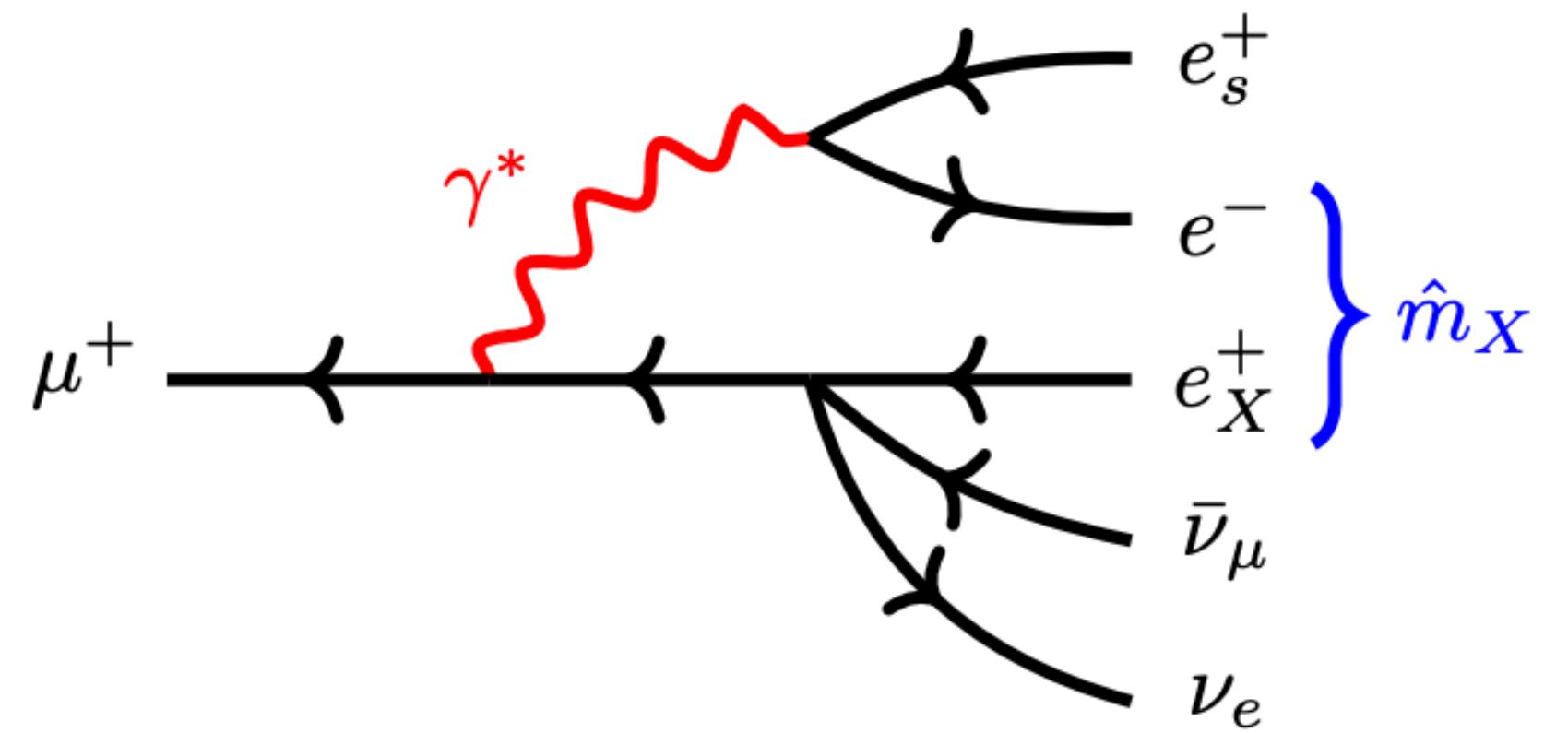


For a  $m_X$  hypothesis, we pick the  $m_{ee}$  combination that is closest to  $m_X$ .



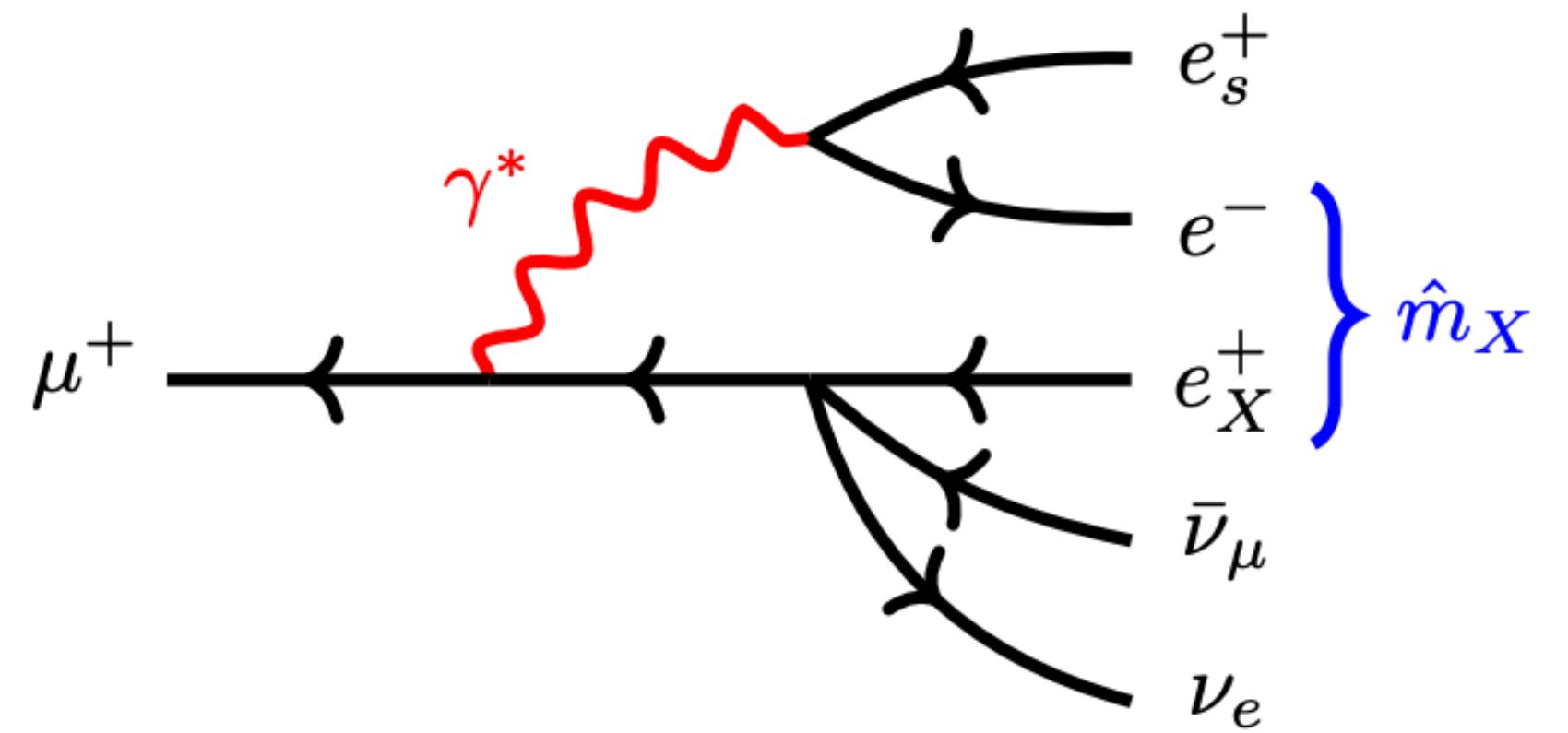
# Utilizing Angular Information

The background has very unique angular spectrum.



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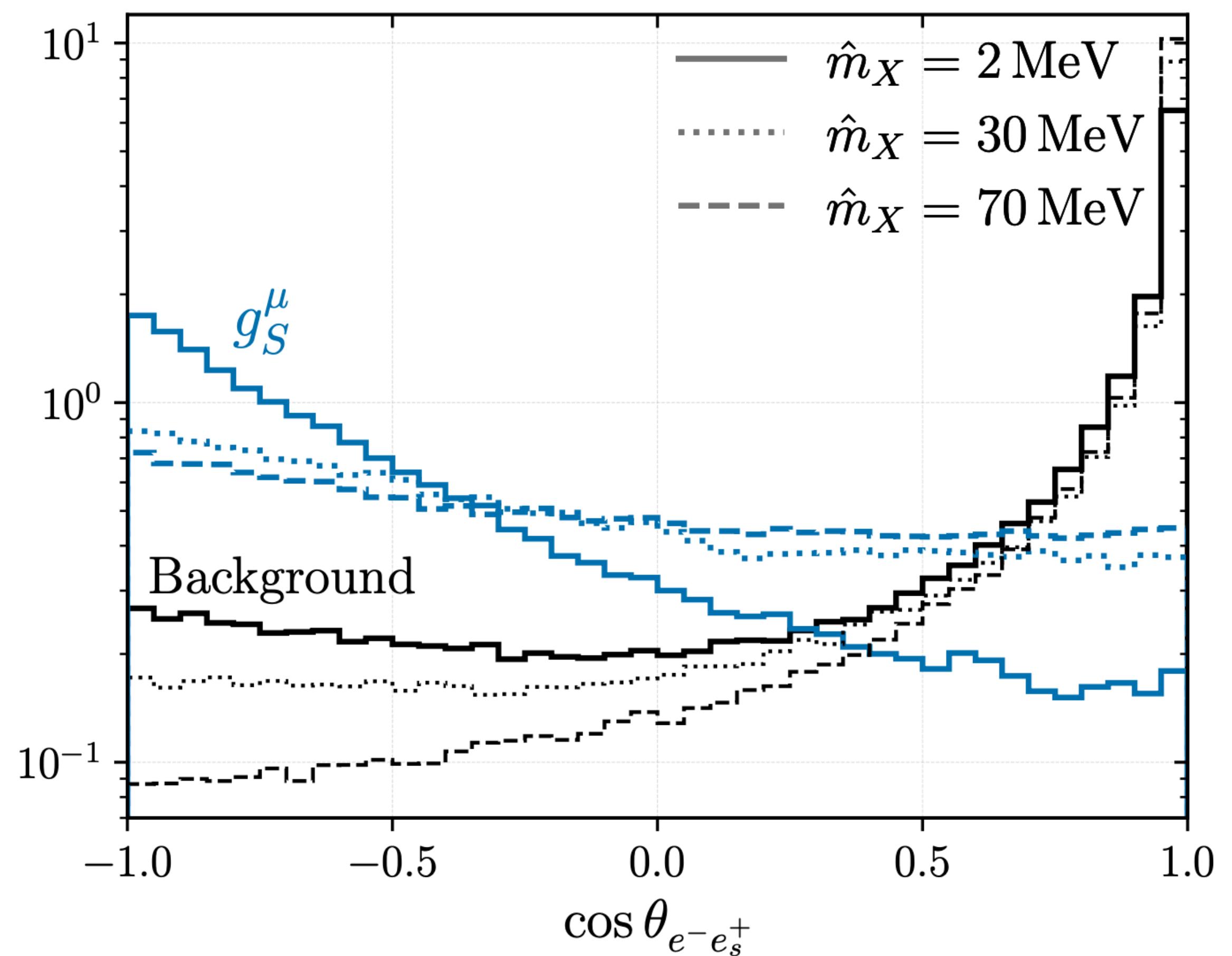
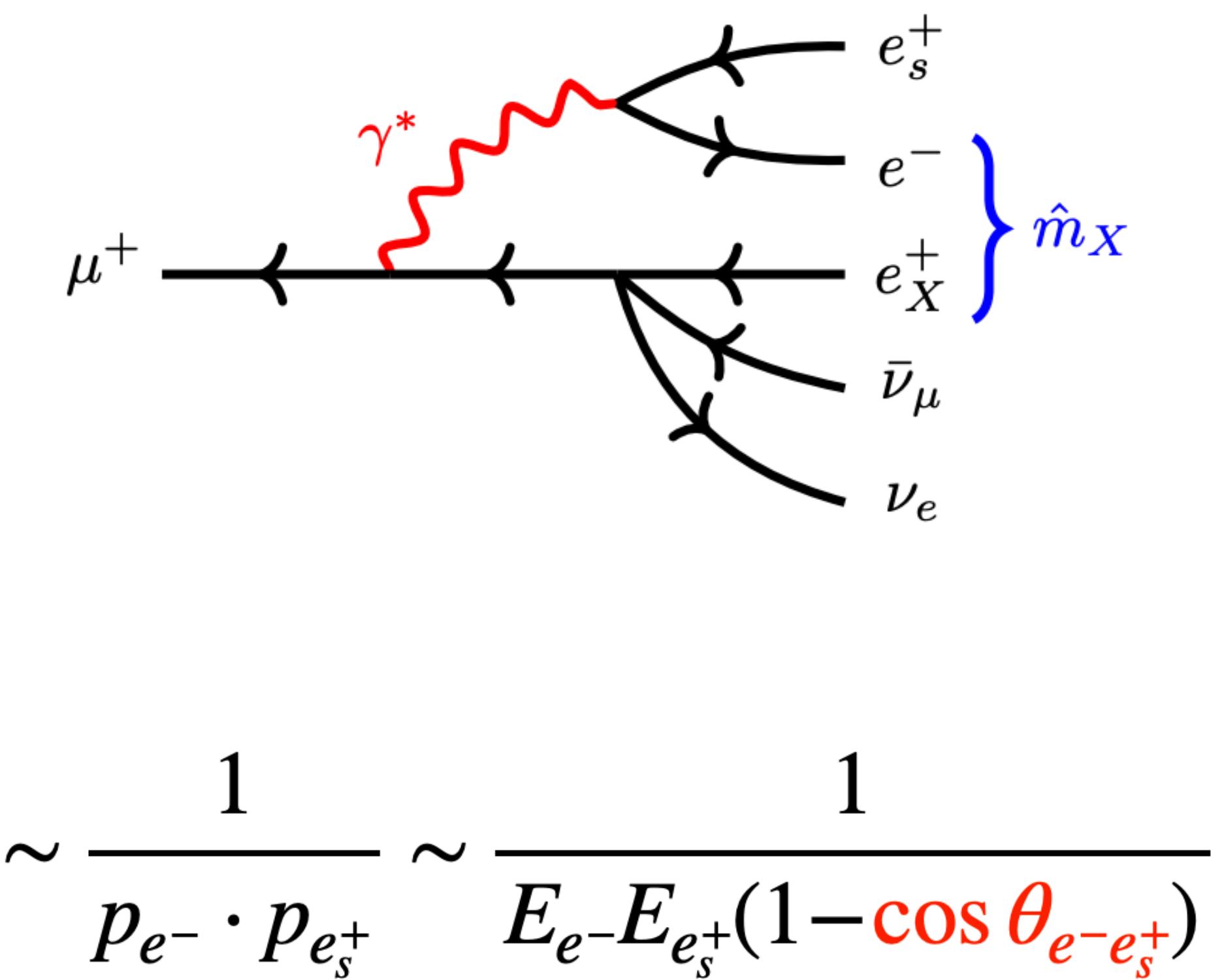
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$$\sim \frac{1}{p_{e^-} \cdot p_{e_s^+}} \sim \frac{1}{E_{e^-} - E_{e_s^+} (1 - \cos \theta_{e^- e_s^+})}$$

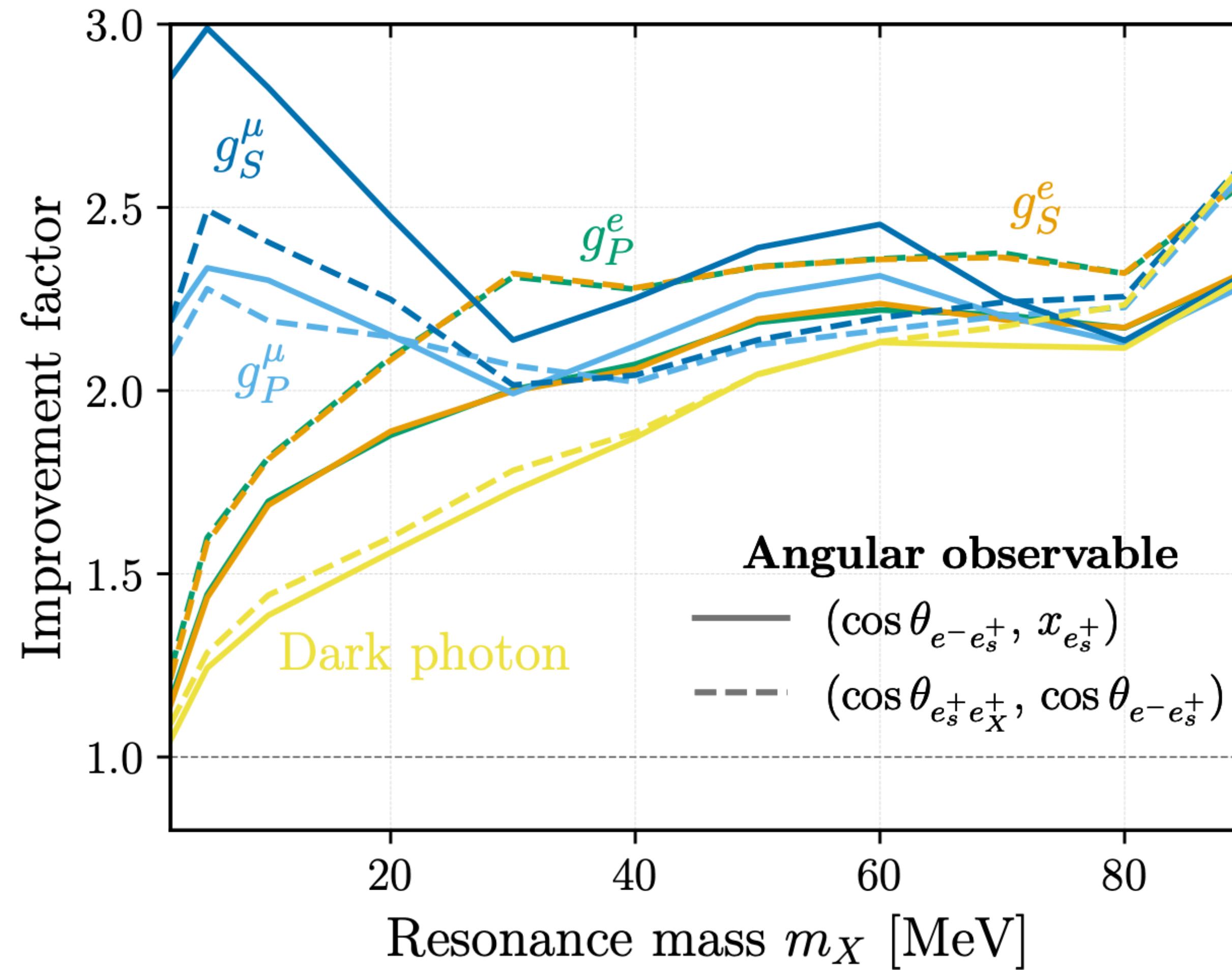
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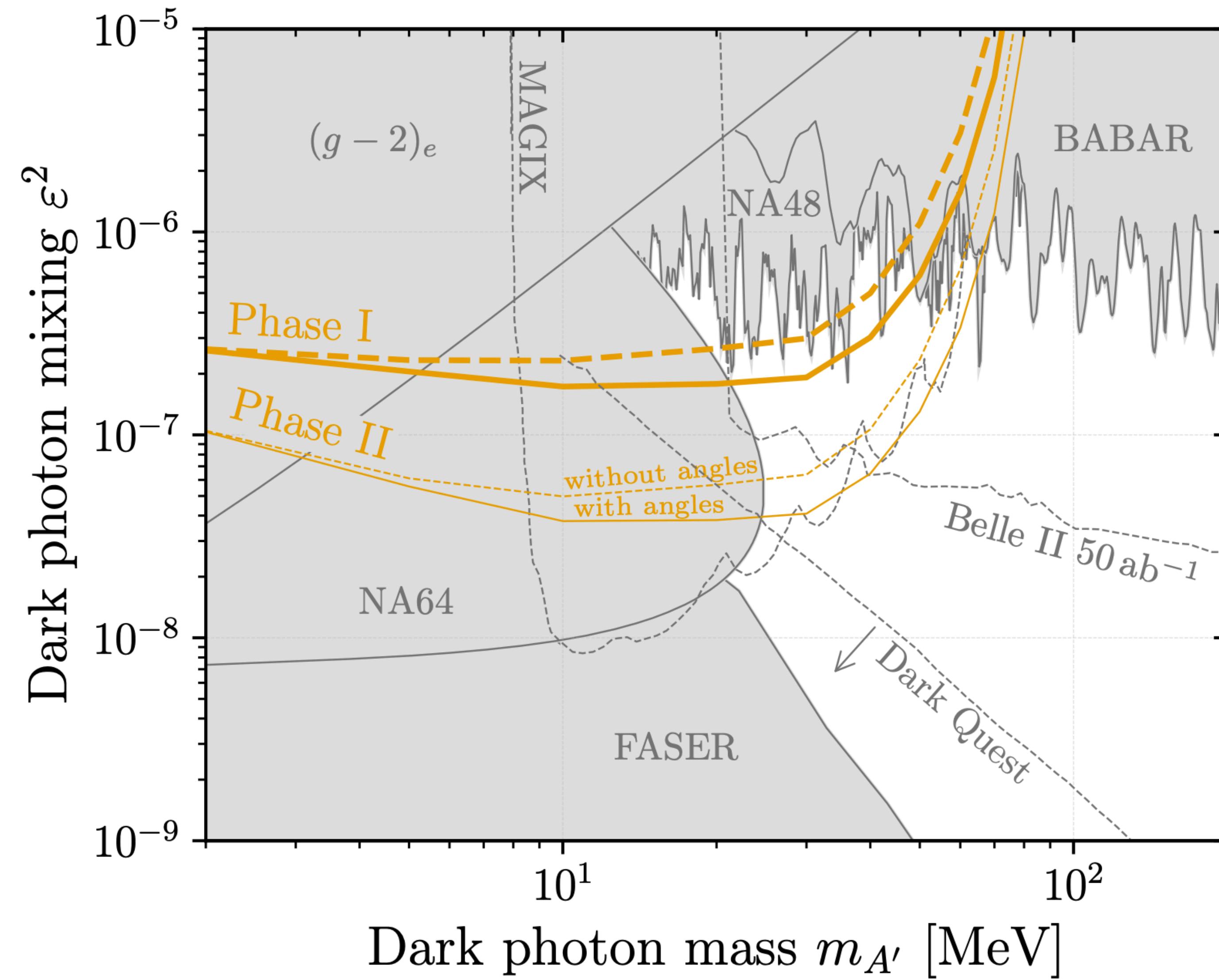
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We achieve a gain in sensitivity relative to normal bump-hunt.



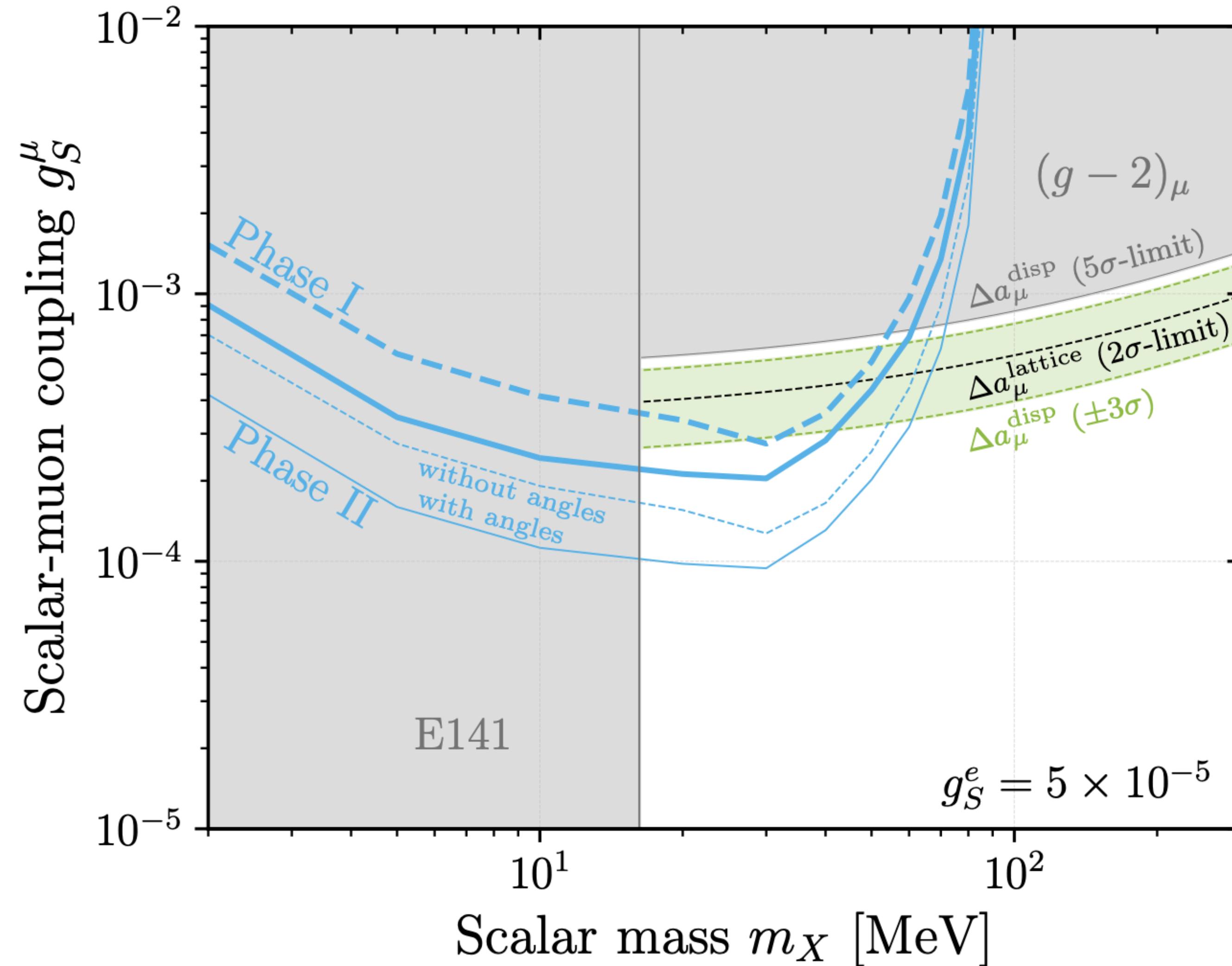
# Results

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# Conclusion

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## CLFV

- $\mu \rightarrow 3e + a$  is a strong alternative search for CLFV axions at Mu $\tilde{3}e$ .

## CLFC

- Angular information improves searches for flavor conserving light particles.
- We explored a variety of different models (more shown in the paper) and identified those which may (or may not) be seen at Mu $\tilde{3}e$ .

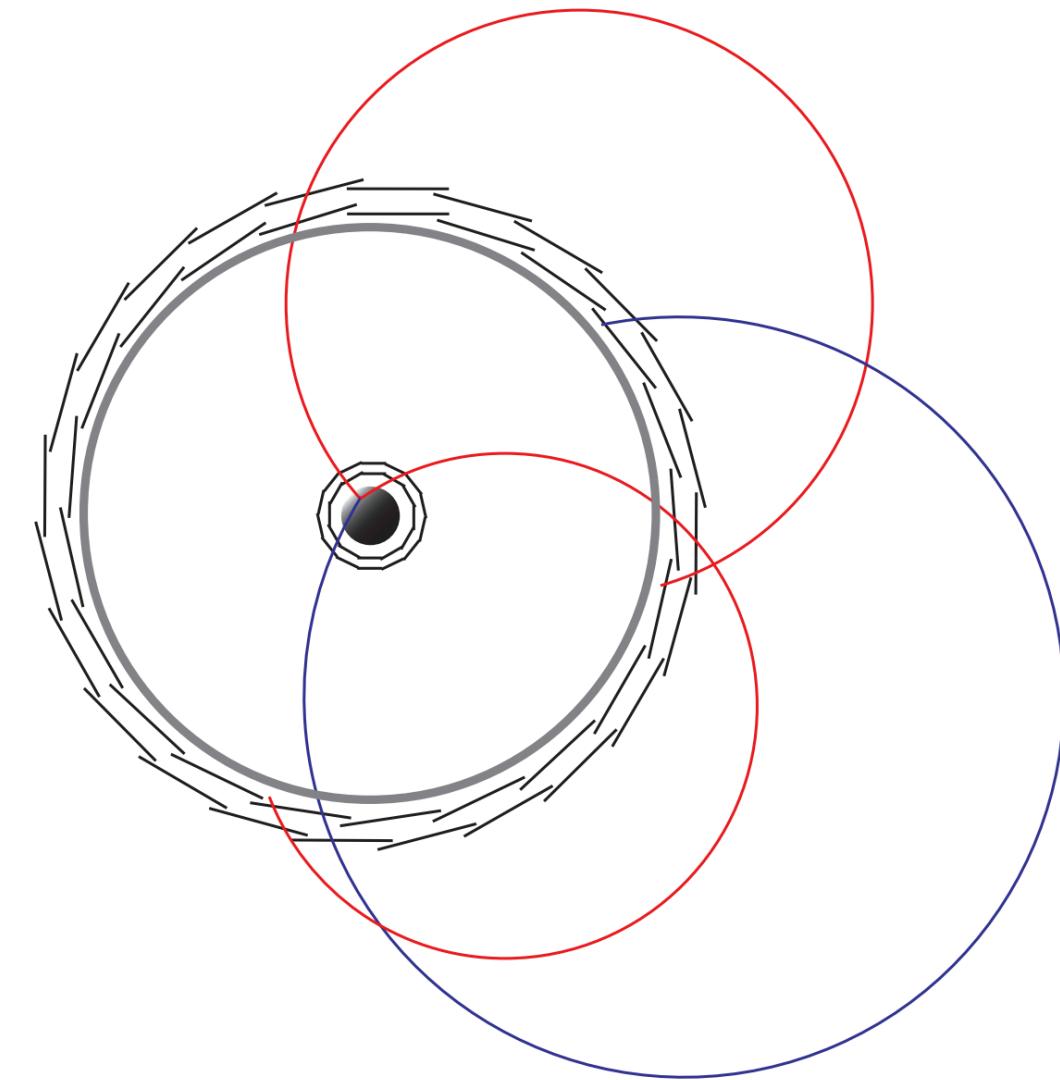
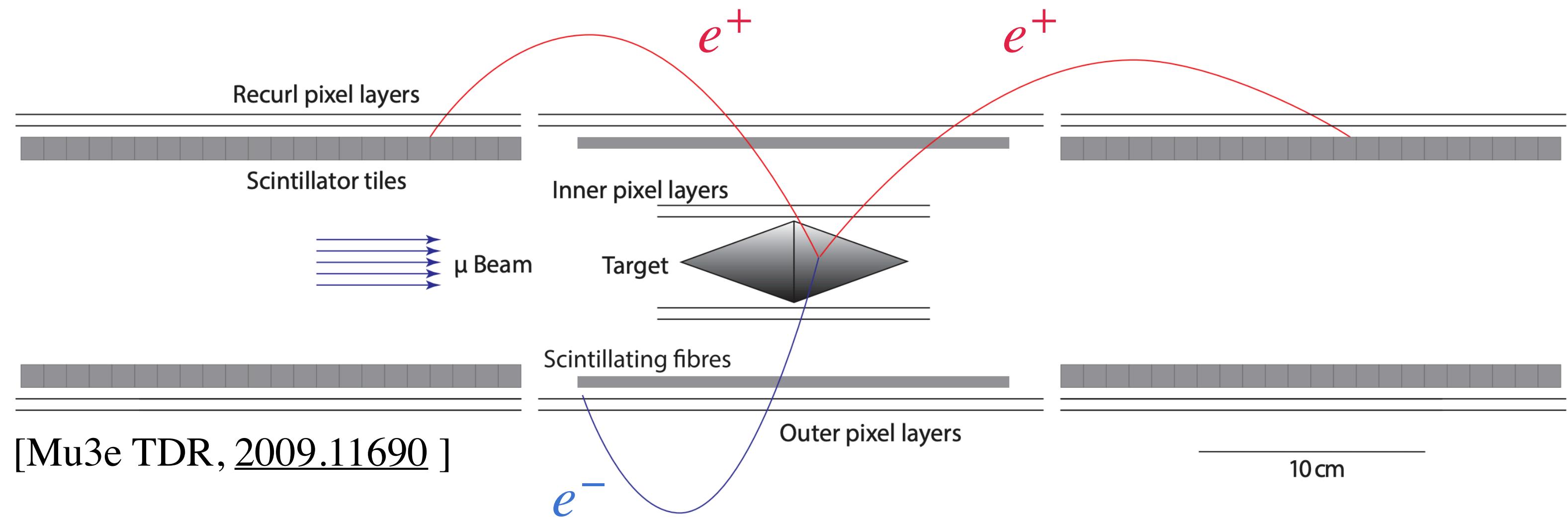
# Backup

# Why Muons

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1. We can make many of them. ( $10^{16} - 10^{18}$ )
2. Long lifetime greatly enhances effects of BSM on decays.
3. Can explore interesting lepton flavor violating interactions.

# The Mu3e Experiment



- $10^8$  muons on target per second.
- Optimized for search for coincident  $e^+e^+e^-$  with  $\sum_i \vec{p}_i = 0$  and  $m_{e^+e^+e^-} = m_\mu$ .
- $\sigma_p \sim (0.1 - 0.5)$  MeV for long tracks (using pixel layers with  $x/X_0 = 0.1\%$ ).

