Fusing photons into nothing,
a new search for invisible ALPs and Dark Matter at Belle II

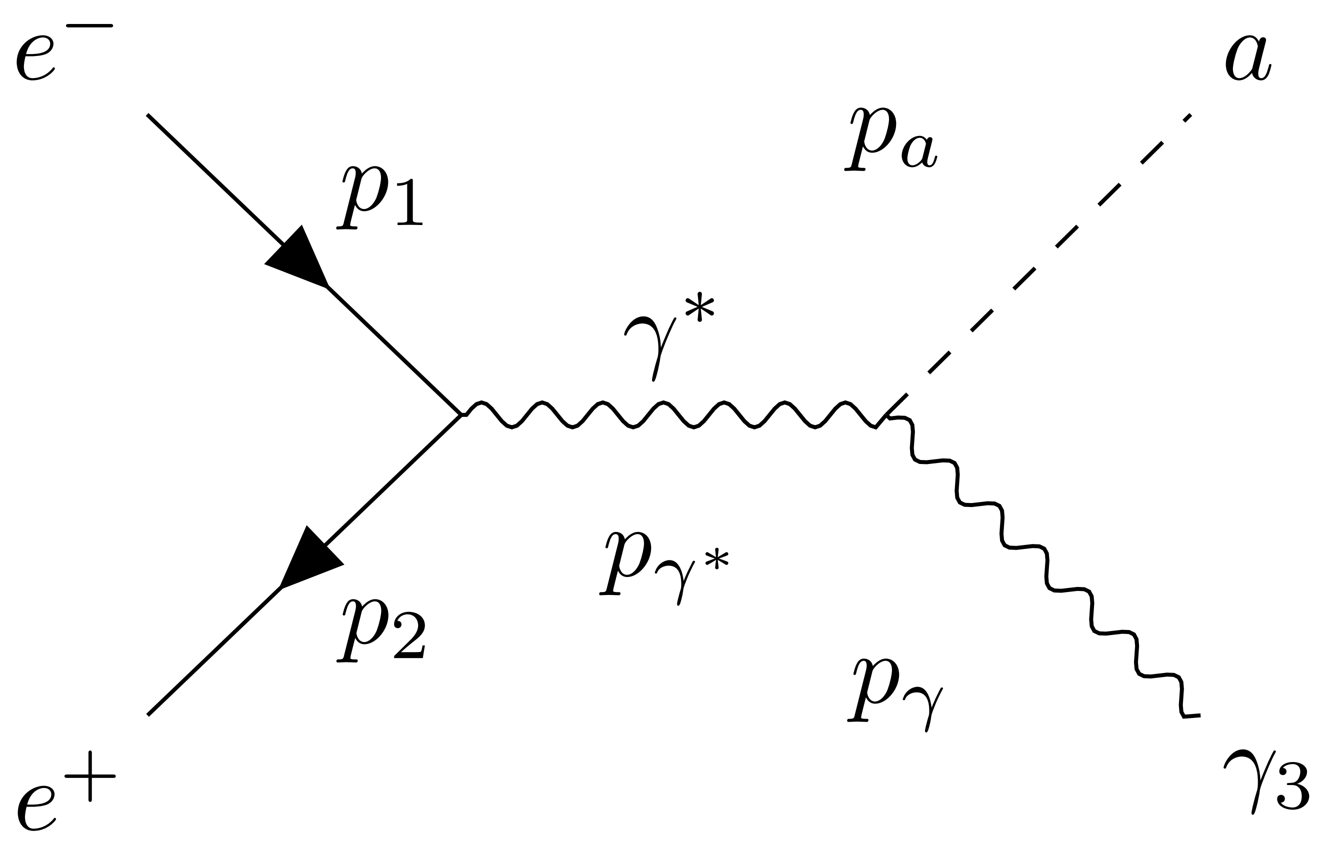
Francesca Acanfora - 2307.06369

In collaboration with R. Franceschini, A. Mastroddi, D. Redigolo

Francesca Acanfora, 04-07-2024, Karlsruhe Institute of Technology, TTP

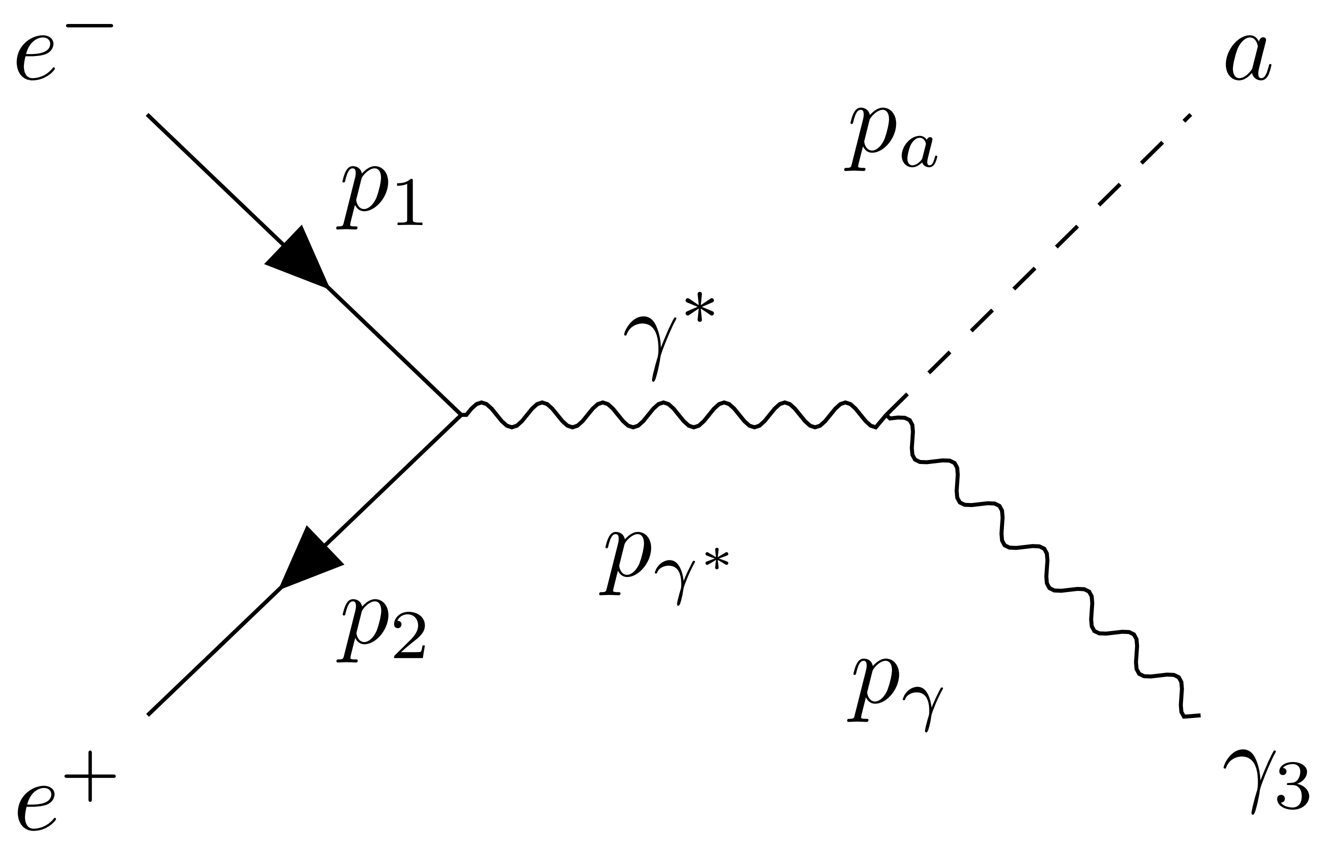
Karlsruher Institut für Technologie

$$\mathscr{L} = \frac{1}{2}(\partial_\mu a)^2 - \frac{m_a^2}{2}a^2 - \frac{g_{a\gamma\gamma}}{4}aF_{\mu\nu}\tilde{F}^{\mu\nu}$$
$$+\frac{i}{2}\bar{\chi}\gamma^\mu\partial_\mu\chi + \frac{M_\chi}{2}\bar{\chi}\chi + \frac{g_{a\chi\chi}}{2}M_\chi a\bar{\chi}\gamma_5\chi$$



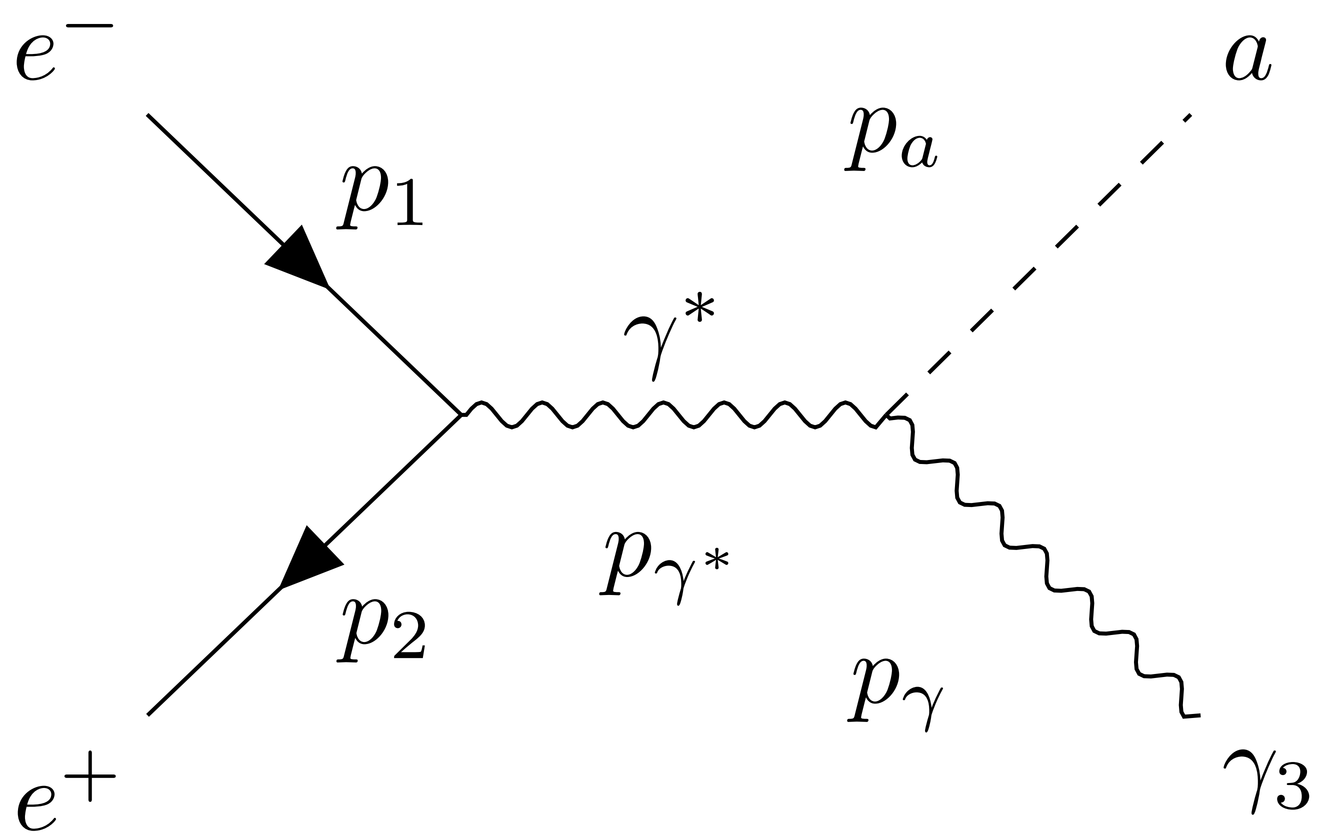
ALP-strahlung

$$\mathscr{L} = \frac{1}{2}(\partial_\mu a)^2 - \frac{m_a^2}{2}a^2 - \frac{g_{a\gamma\gamma}}{4}aF_{\mu\nu}\tilde{F}^{\mu\nu}$$
$$+\frac{i}{2}\bar{\chi}\gamma^\mu\partial_\mu\chi + \frac{M_\chi}{2}\bar{\chi}\chi + \frac{g_{a\chi\chi}}{2}M_\chi a\bar{\chi}\gamma_5\chi$$

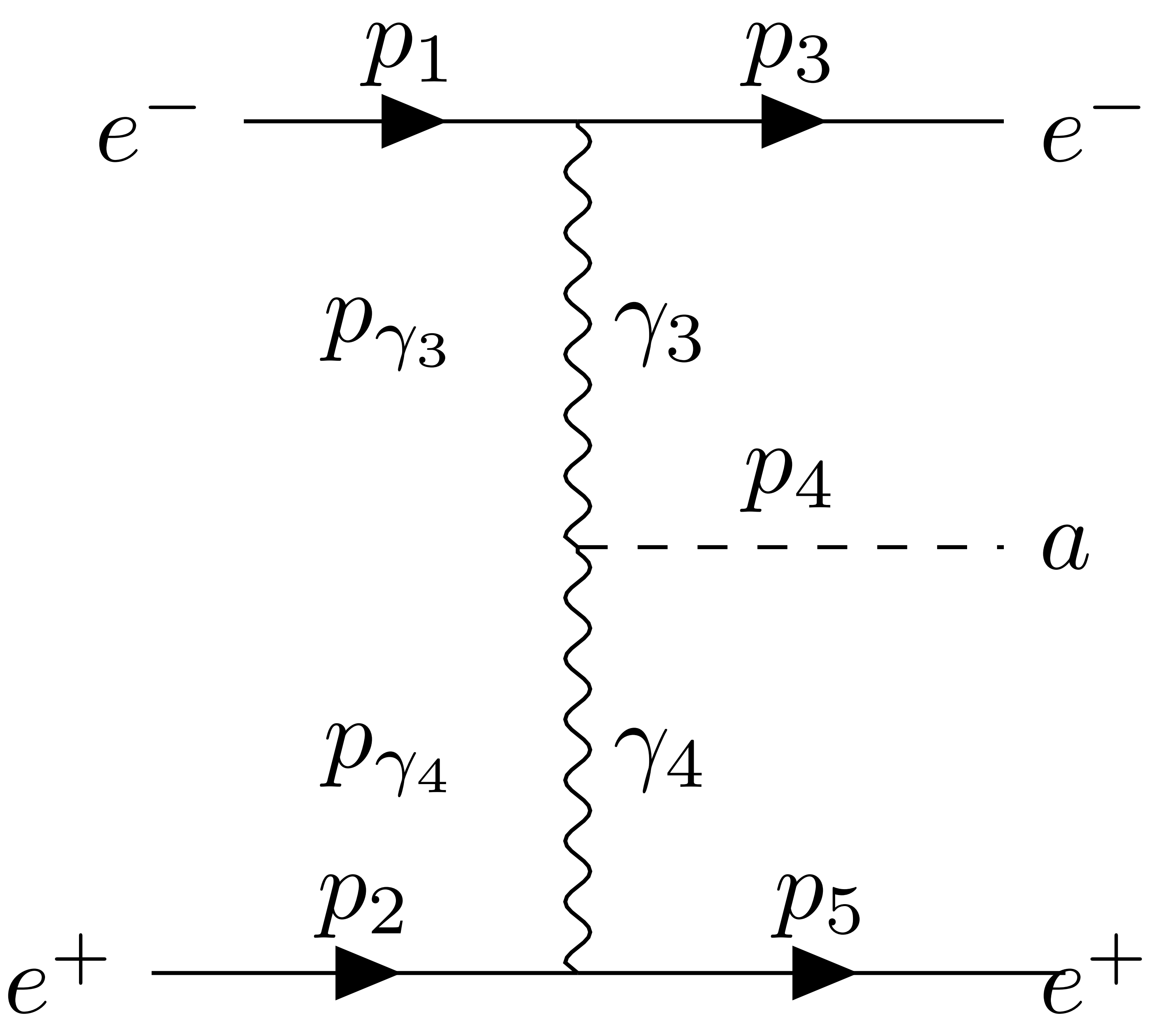


ALP-strahlung

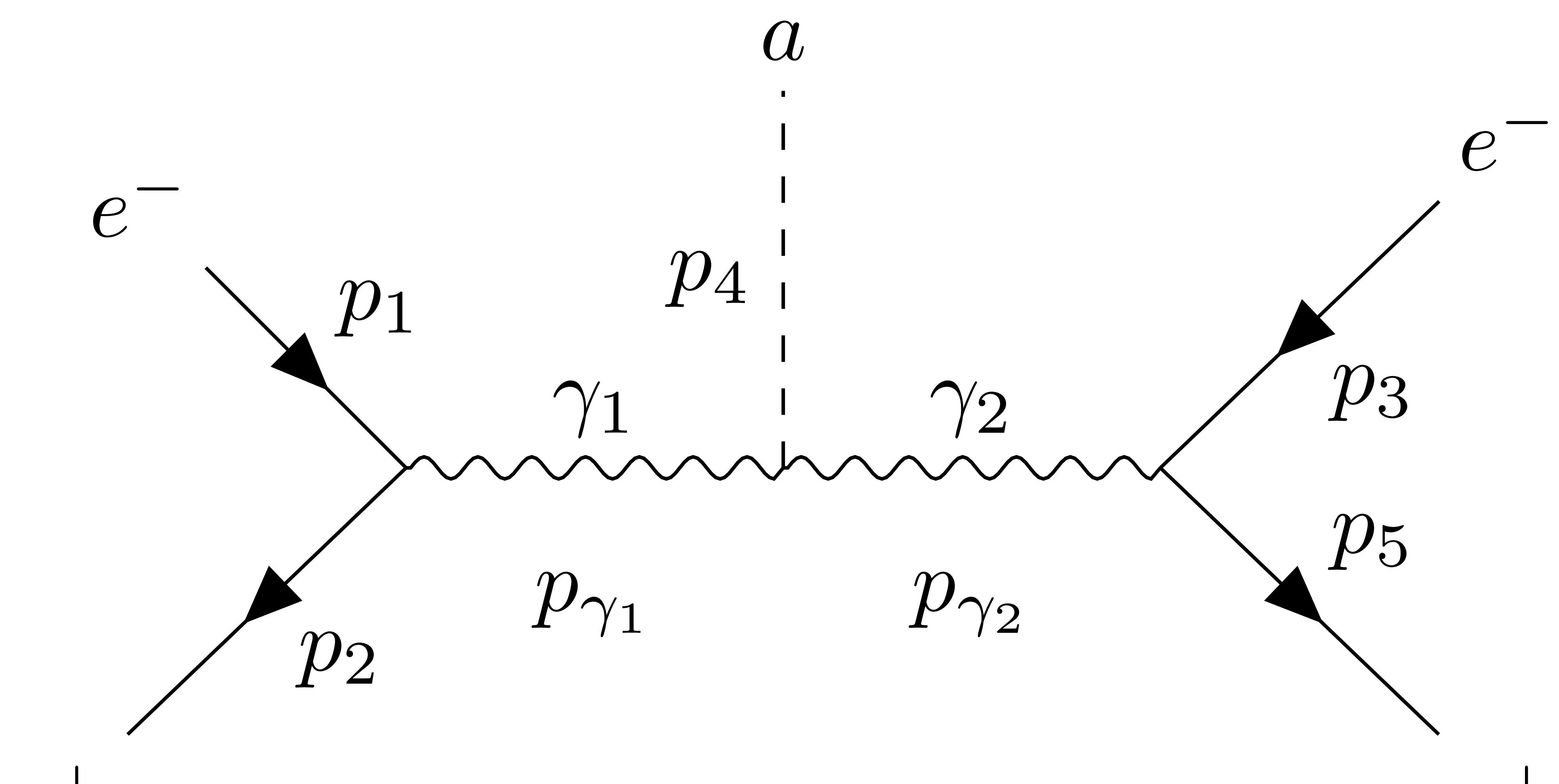
$$\mathscr{L} = \frac{1}{2}(\partial_\mu a)^2 - \frac{m_a^2}{2}a^2 - \frac{g_{a\gamma\gamma}}{4}aF_{\mu\nu}\tilde{F}^{\mu\nu} + \frac{i}{2}\bar{\chi}\gamma^\mu\partial_\mu\chi + \frac{M_\chi}{2}\bar{\chi}\chi + \frac{g_{a\chi\chi}}{2}M_\chi a\bar{\chi}\gamma_5\chi$$



ALP-strahlung



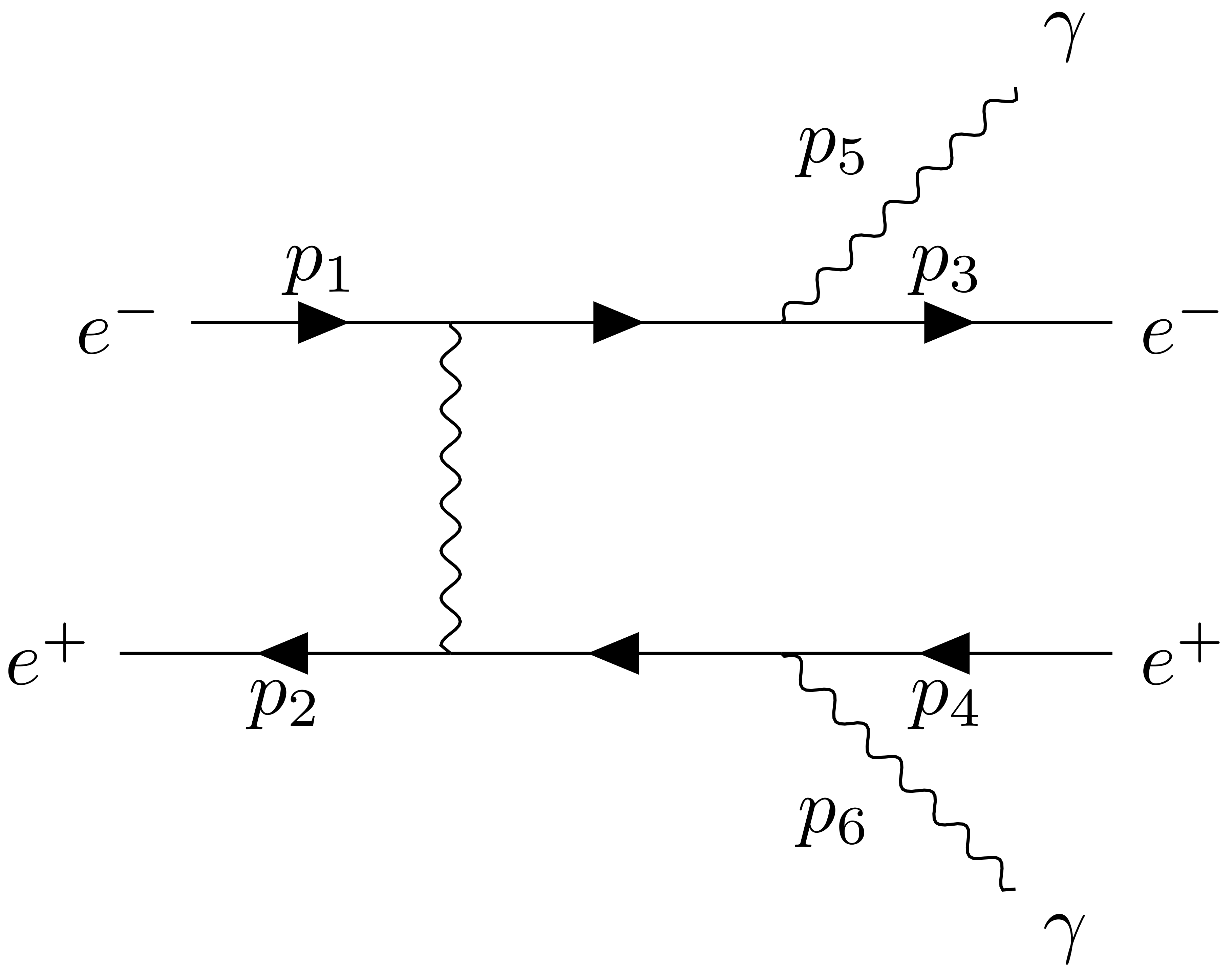
VBF



Dalitz

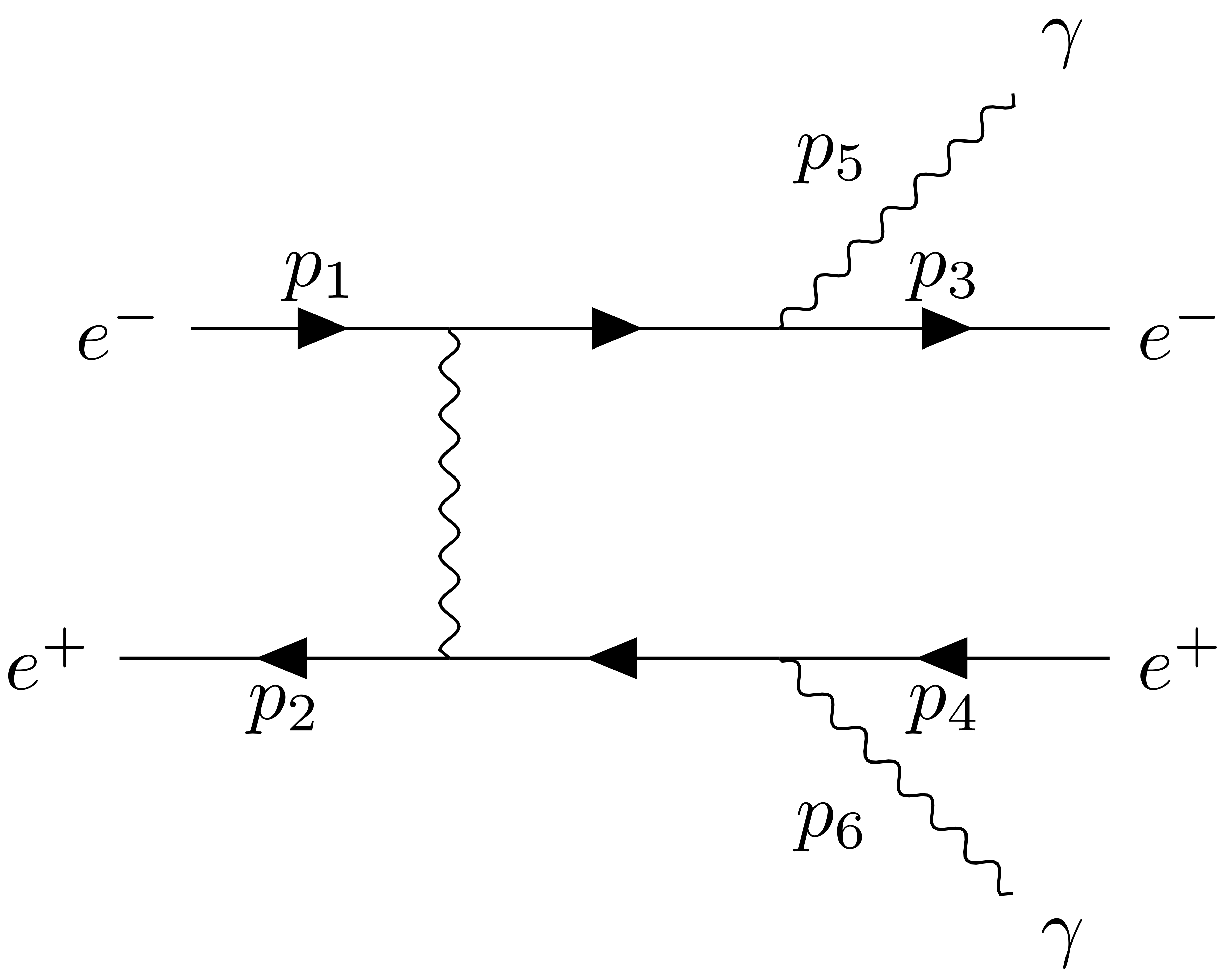
Backgrounds

Backgrounds

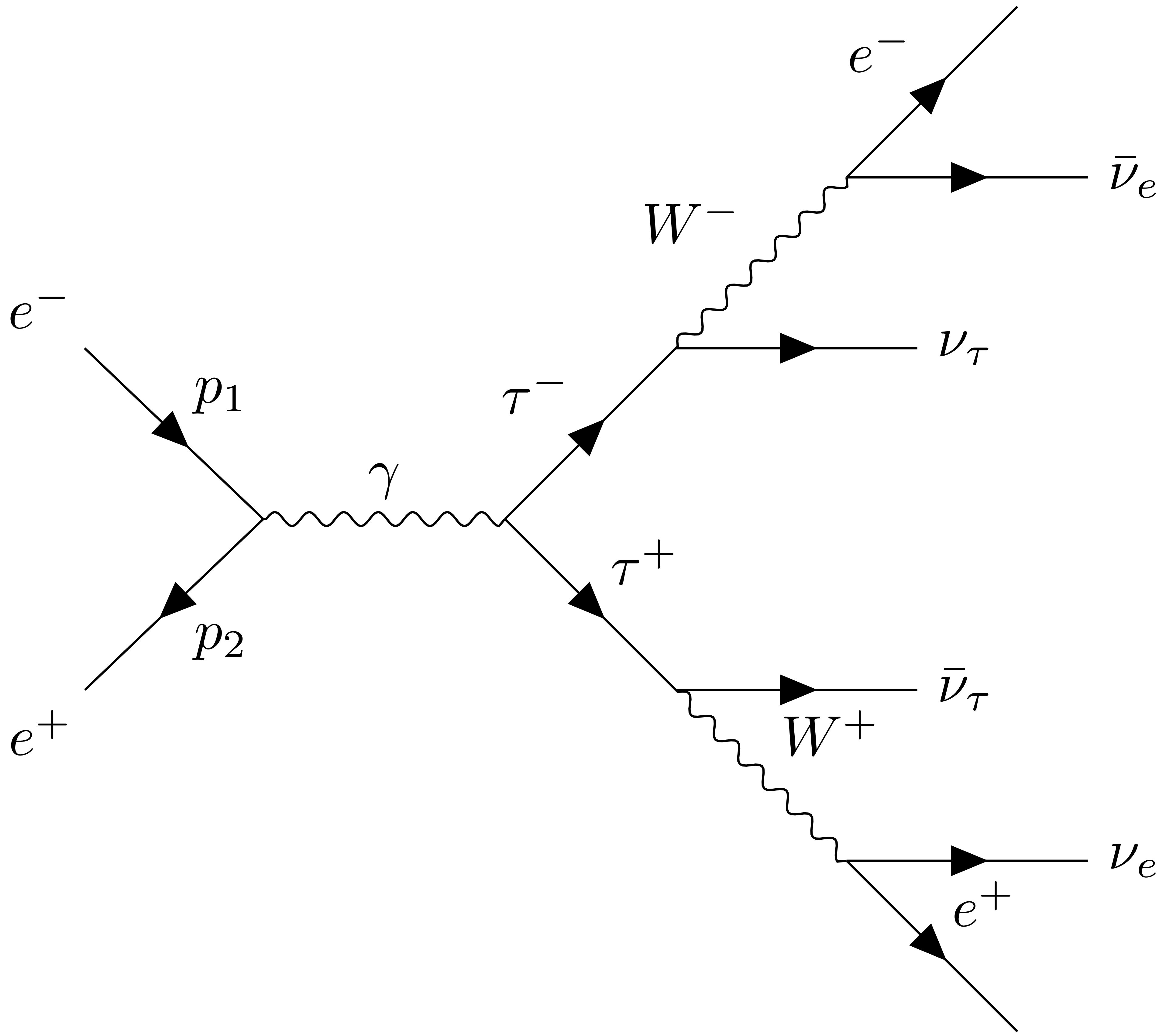


QED^2

Backgrounds

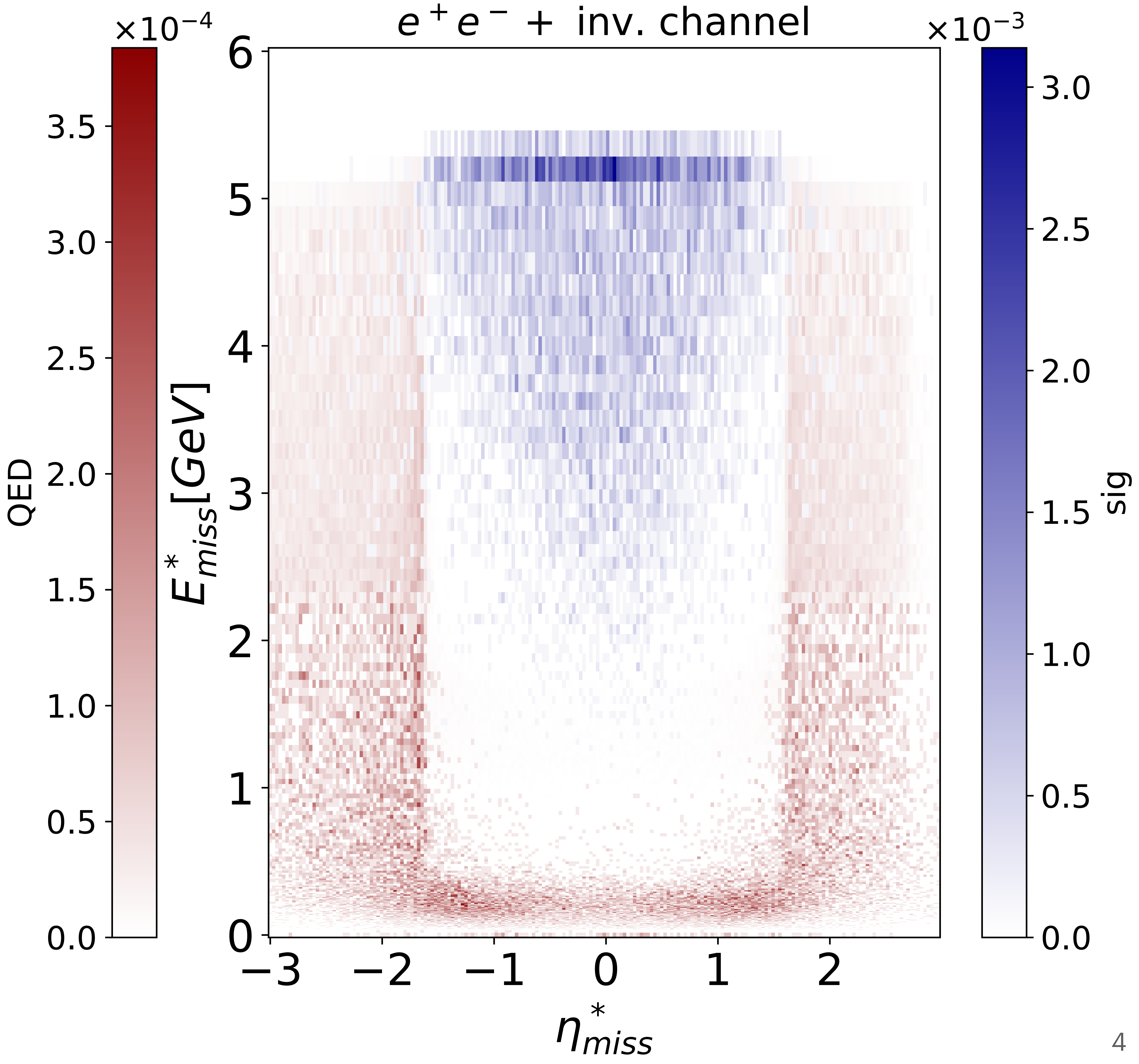


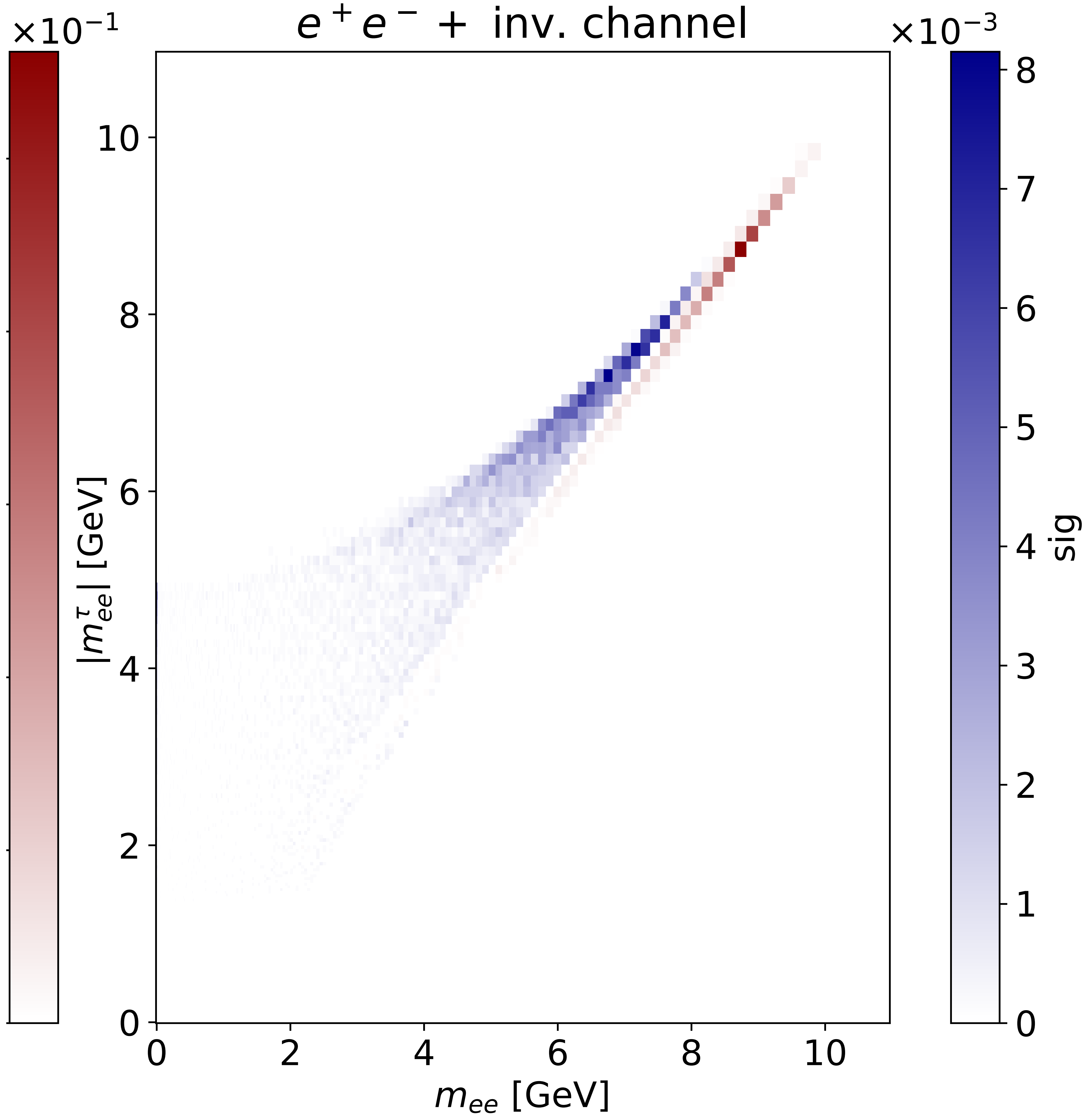
QED^2

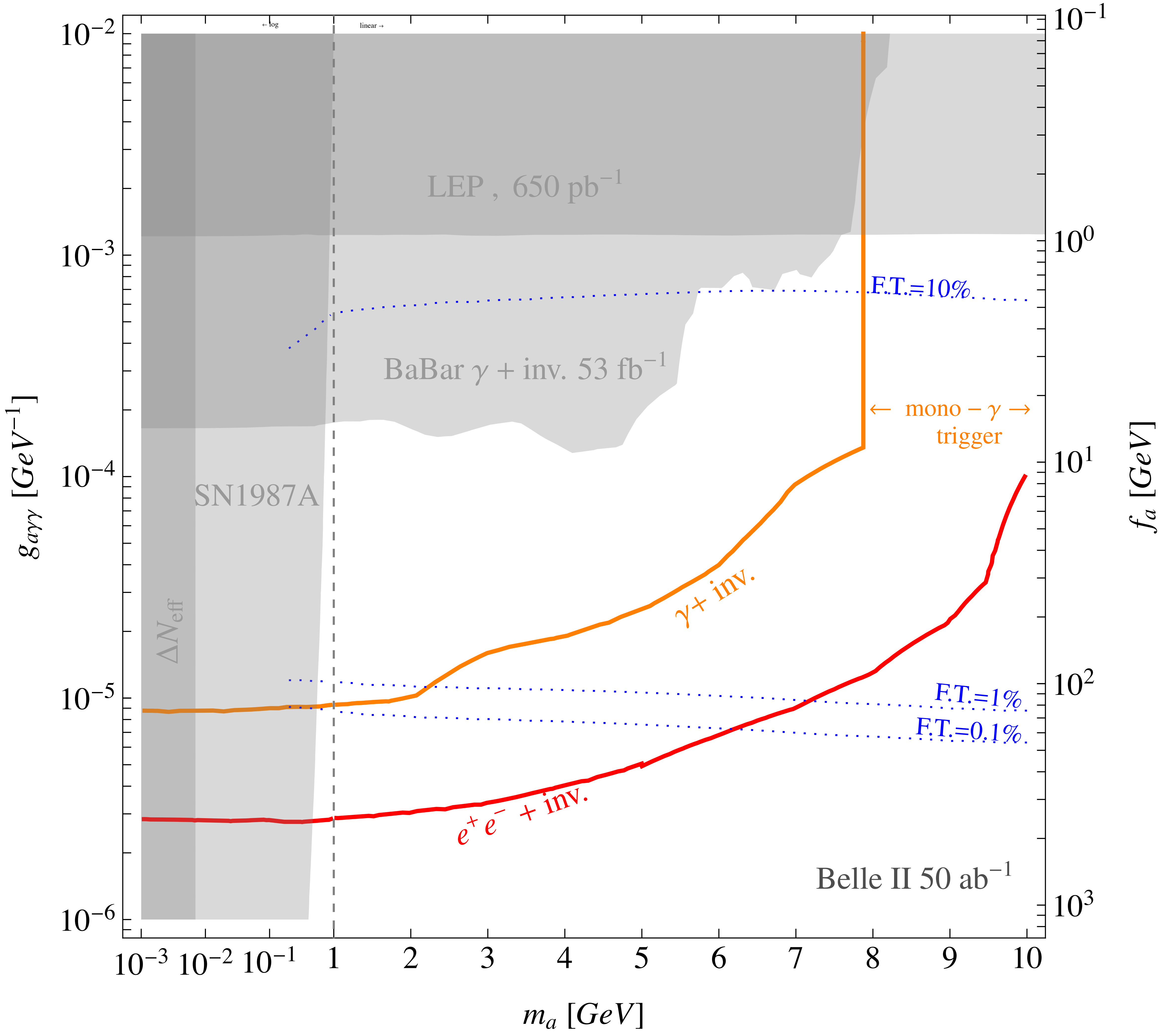


$\tau\tau$

Background killing





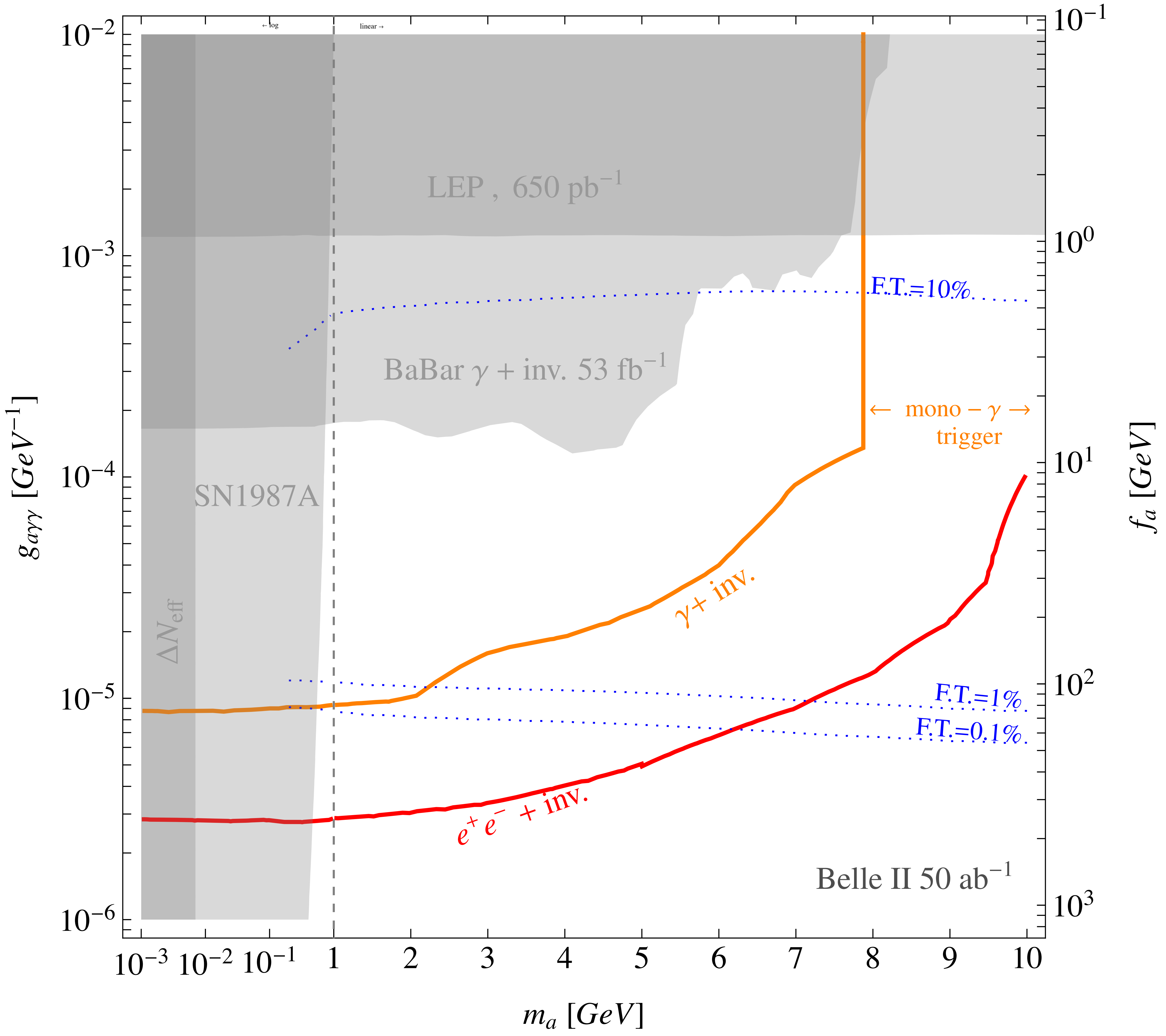


1709.0000

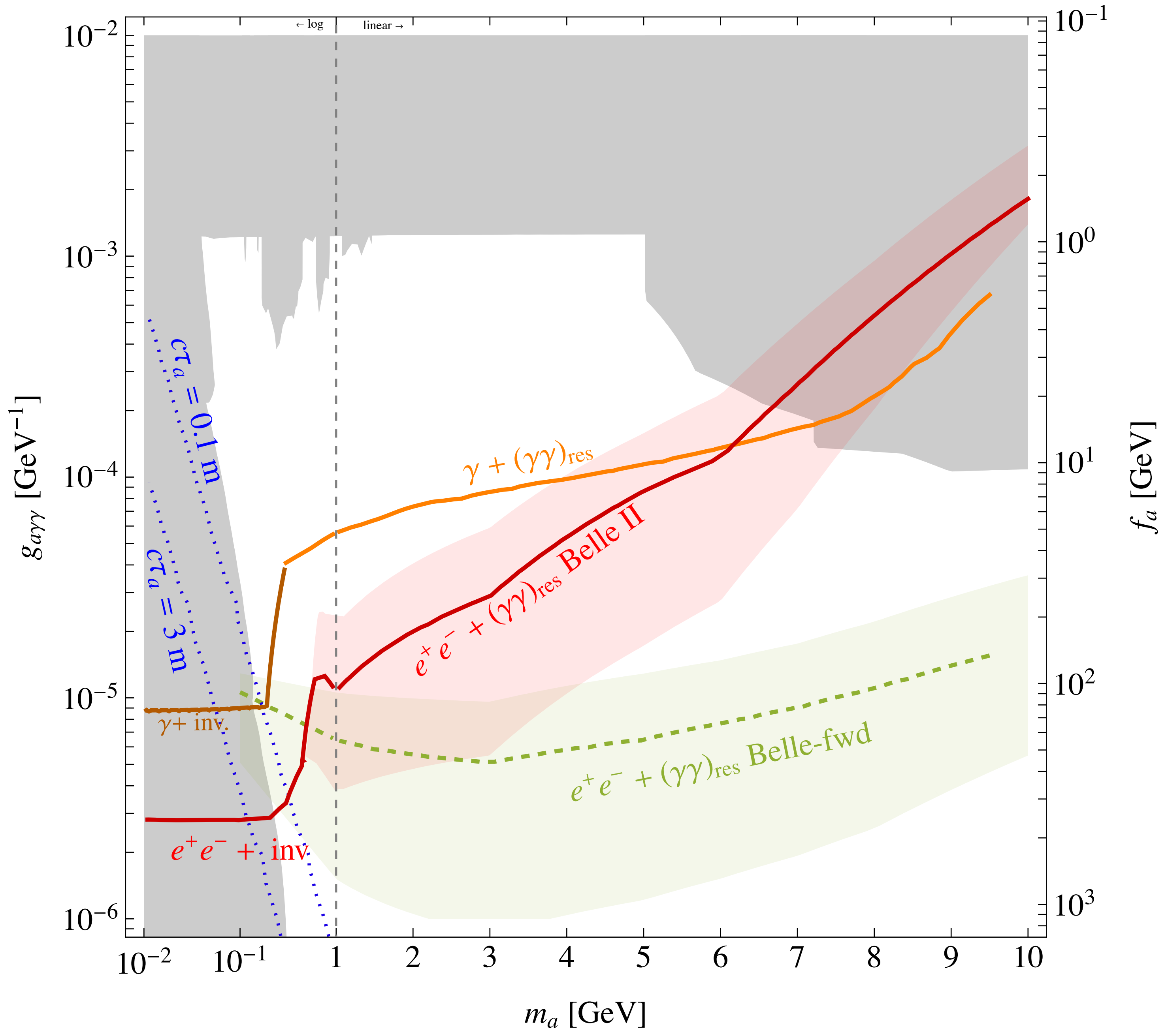
2307.0636

1709.0000

2307.0636

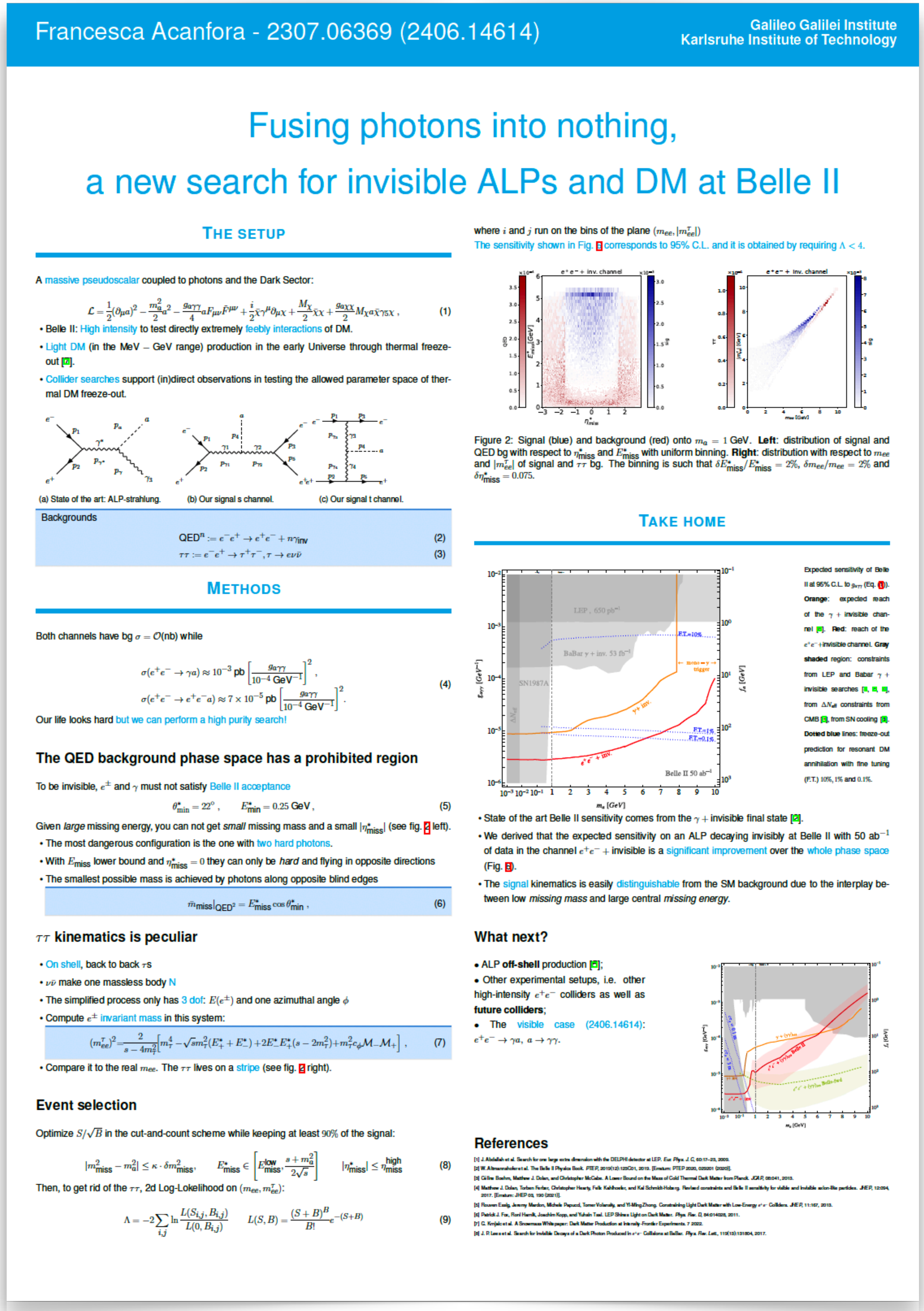


Bonus for you!
The visible case



2406.14614

Thank you :)


Francesca Acanfora - 2307.06369 (2406.14614)
Galileo Galilei Institute
Karlsruhe Institute of Technology
Fusing photons into nothing,
a new search for invisible ALPs and DM at Belle II
The setup
A massive pseudoscalar coupled to photons and the Dark Sector:
Belle II: High intensity to test directly extremely feebly interactions of DM.
Light DM (in the MeV – GeV range) production in the early Universe through thermal freeze-out
Collider searches support (in)direct observations in testing the allowed parameter space of thermal DM freeze-out.
(a) State of the art: ALP-strahlung.
(b) Our signal s channel.
(c) Our signal t channel.
Backgrounds
Methods
Both channels have bg σ = O(nb) while
Our life looks hard but we can perform a high purity search!
The QED background phase space has a prohibited region
To be invisible, e± and γ must not satisfy Belle II acceptance
The most dangerous configuration is the one with two hard photons.
The smallest possible mass is achieved by photons along opposite blind edges
ττ kinematics is peculiar
On shell, back to back τs
Event selection
Then, to get rid of the ττ, 2d Log-Lokelihood on
Take home
State of the art Belle II sensitivity comes from the γ + invisible final state
We derived that the expected sensitivity on an ALP decaying invisibly at Belle II with 50 ab−1 of data in the channel e+e− + invisible is a significant improvement over the whole phase space
The signal kinematics is easily distinguishable from the SM background due to the interplay between low missing mass and large central missing energy.
What next?
ALP off-shell production
Other experimental setups, i.e. other high-intensity e+e− colliders as well as future colliders;
The visible case (2406.14614): e+e− → γa, a → γγ.
References

Backup slides

What will ALP decay into?

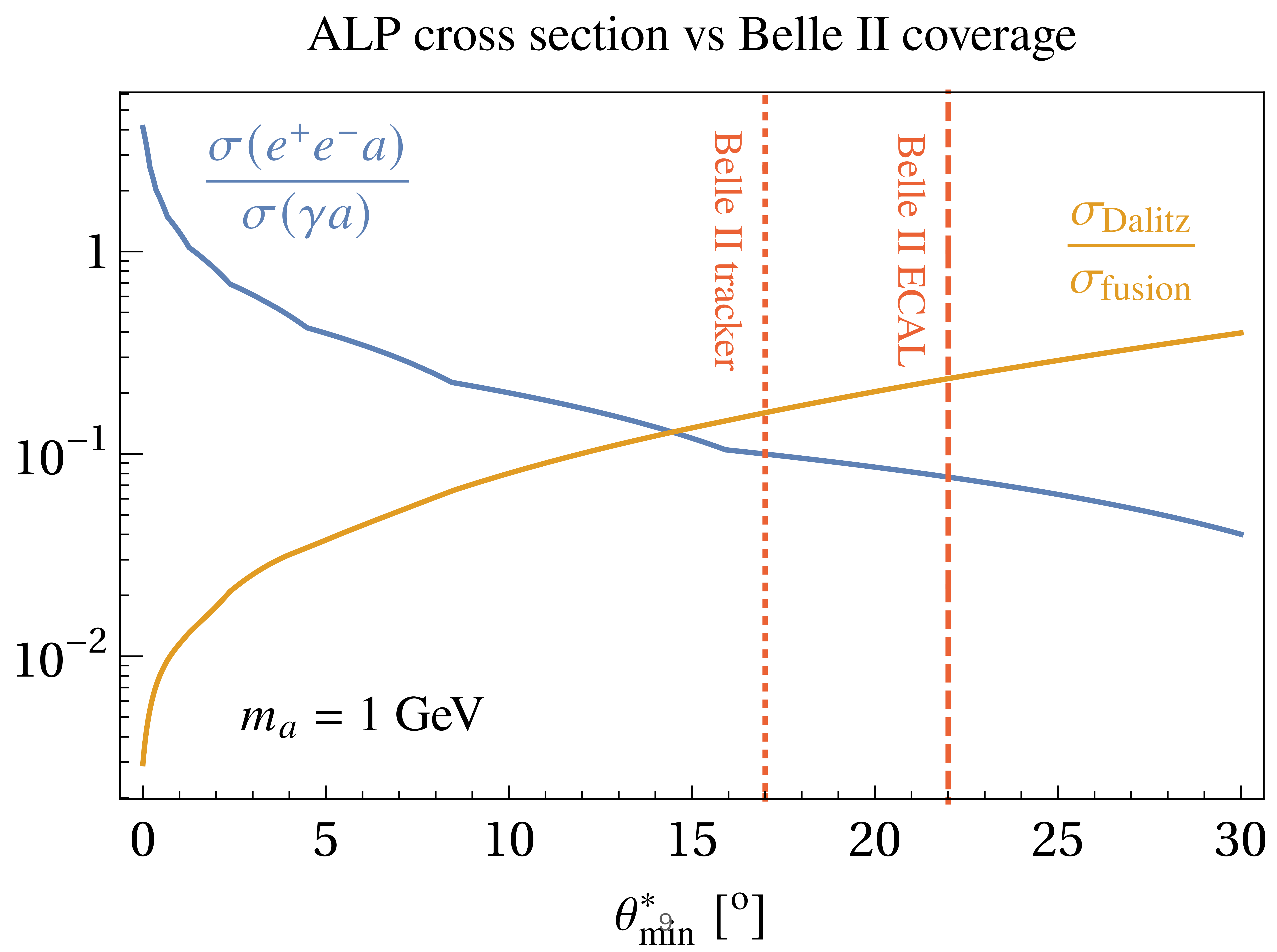
$$\frac{\Gamma(a \to \gamma\gamma)}{\Gamma(a \to \chi\chi)} \sim \left(\frac{\alpha_{\rm em}}{4\pi}\right)^2 \frac{1}{r^2\sqrt{1-4r^2}} \sim \mathcal{O}(10^{-7} - 10^{-6}) \to r \sim 0 \text{ or } r \sim \frac{1}{2}$$

$$r \equiv M_\chi/m_a \lesssim 1/2, \qquad g_{a\gamma\gamma} = \frac{\alpha_{em} c_{\gamma\gamma}}{2\pi f_a} \qquad c_{\gamma\gamma} \sim \mathcal{O}(1) \qquad g_{a\chi\chi} \sim 1/f_a$$

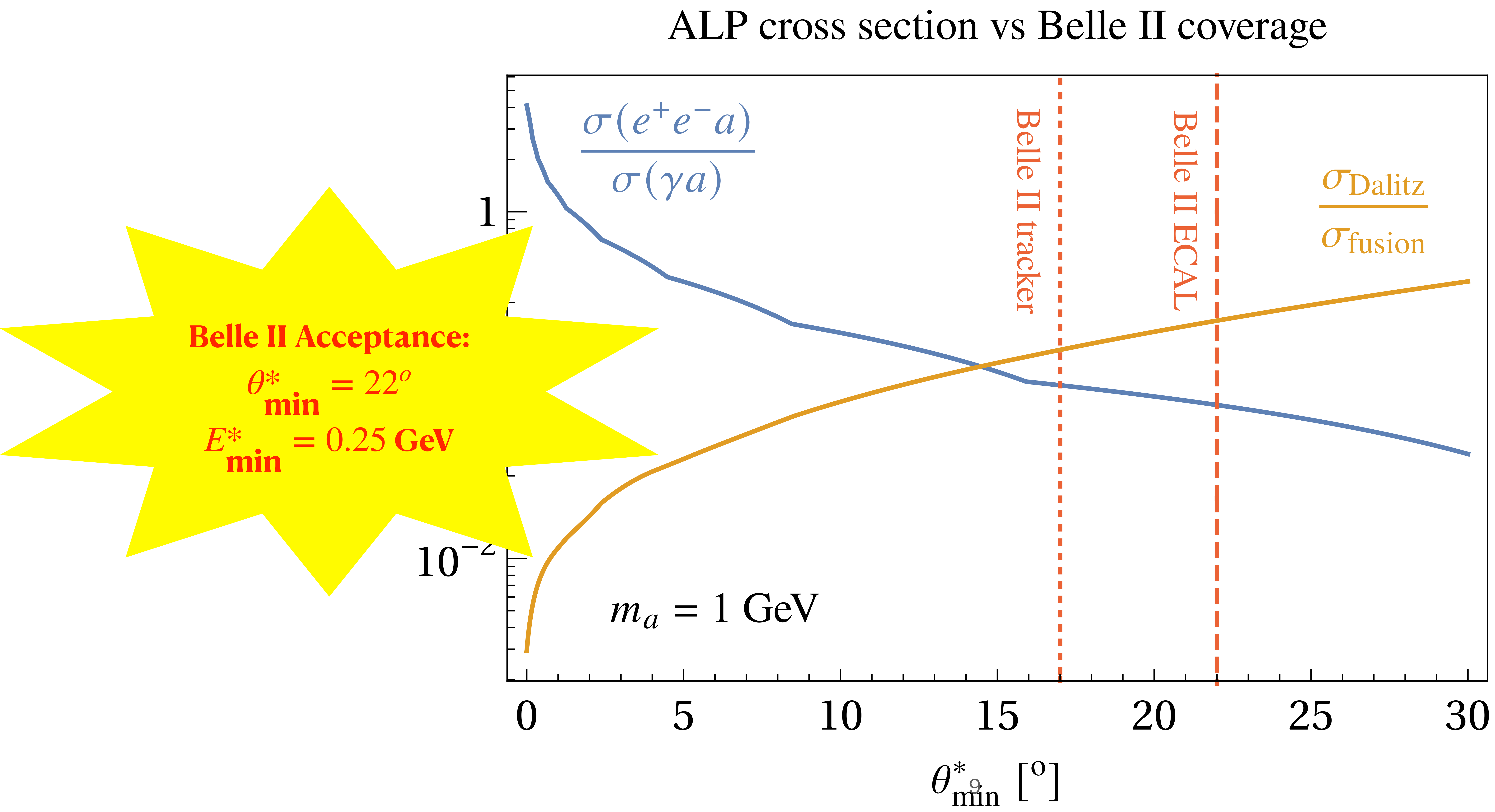
$\frac{1}{r^2}$ comes from the scale dependence of the partial width

$\sqrt{1-4r^2} \to$ phase space suppression of the invisible channel.

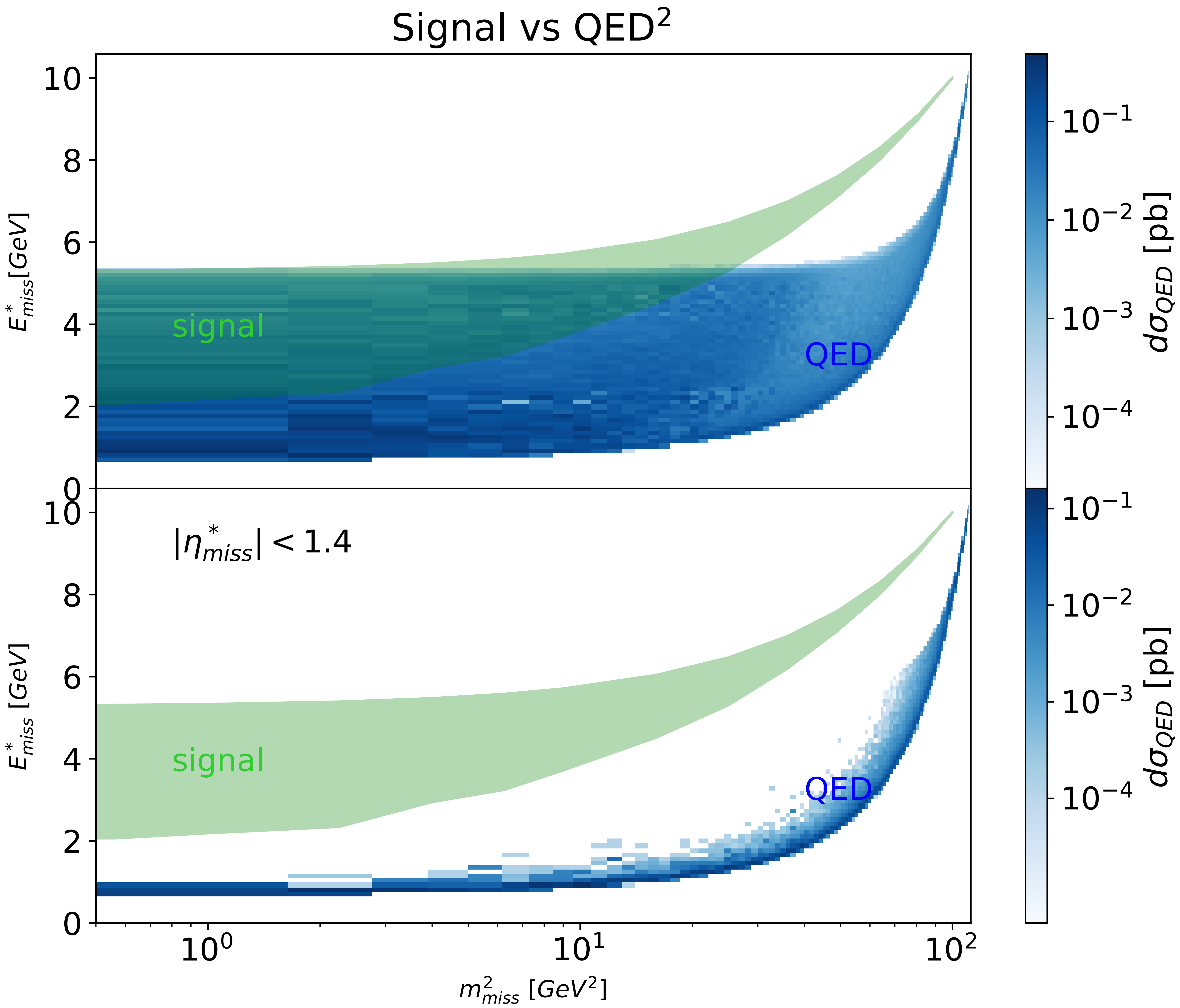
Angular acceptance controls processes hierarchies



Angular acceptance controls processes hierarchies



Effect of selections on QED background



Signal - $\tau\tau$ separation depends on ALP mass