Strong Field Trident Pair-Production

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Theory and Simulations of Photon-Matter Interaction
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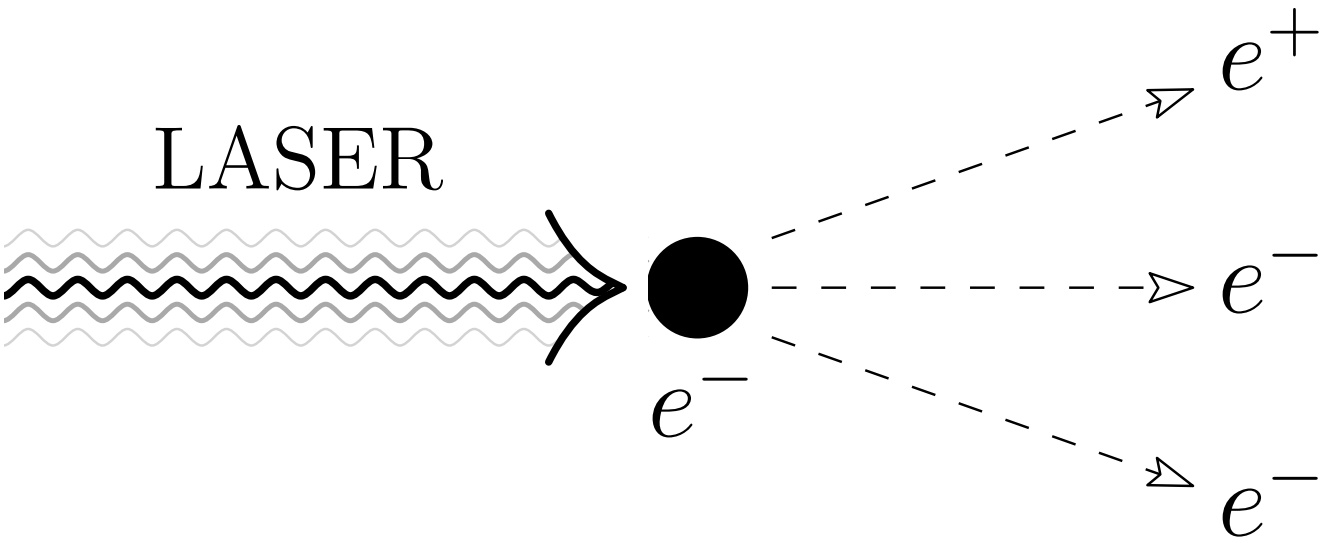
Introduction

Definition: trident process



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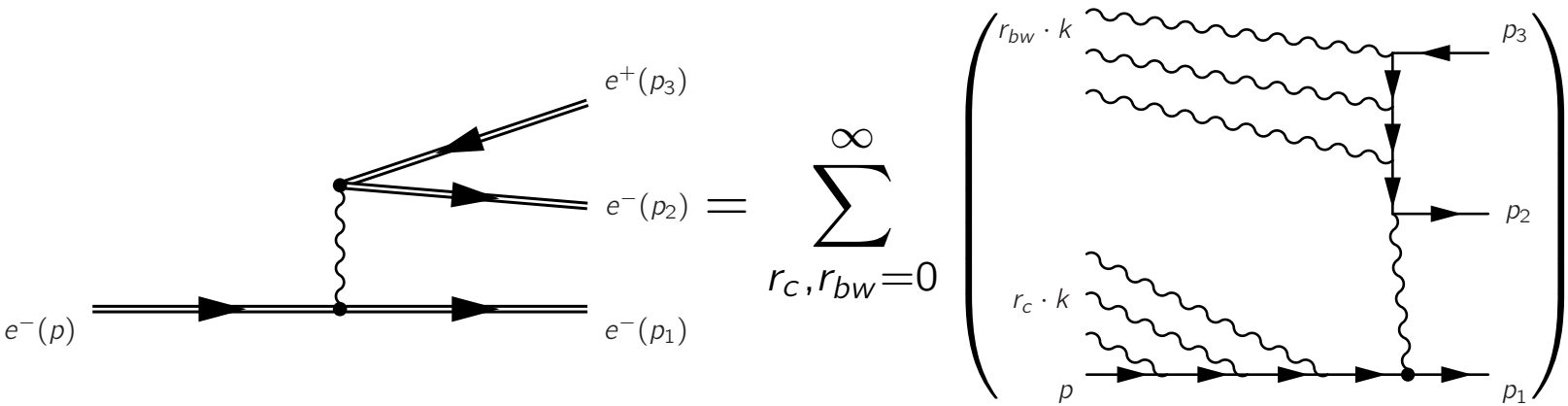
Introduction

Why is trident interesting?

- first experimental access $\rightarrow$ testing multi-photon QED (Burke et al., E-144; 1997)
- complementary to deacy of the quantum vacuum
- first step in seeded QED cascades with full quantum interferences
- pure QED background for dark sector discovery potential

Strong-field trident

Furry-Feynman-Diagram:

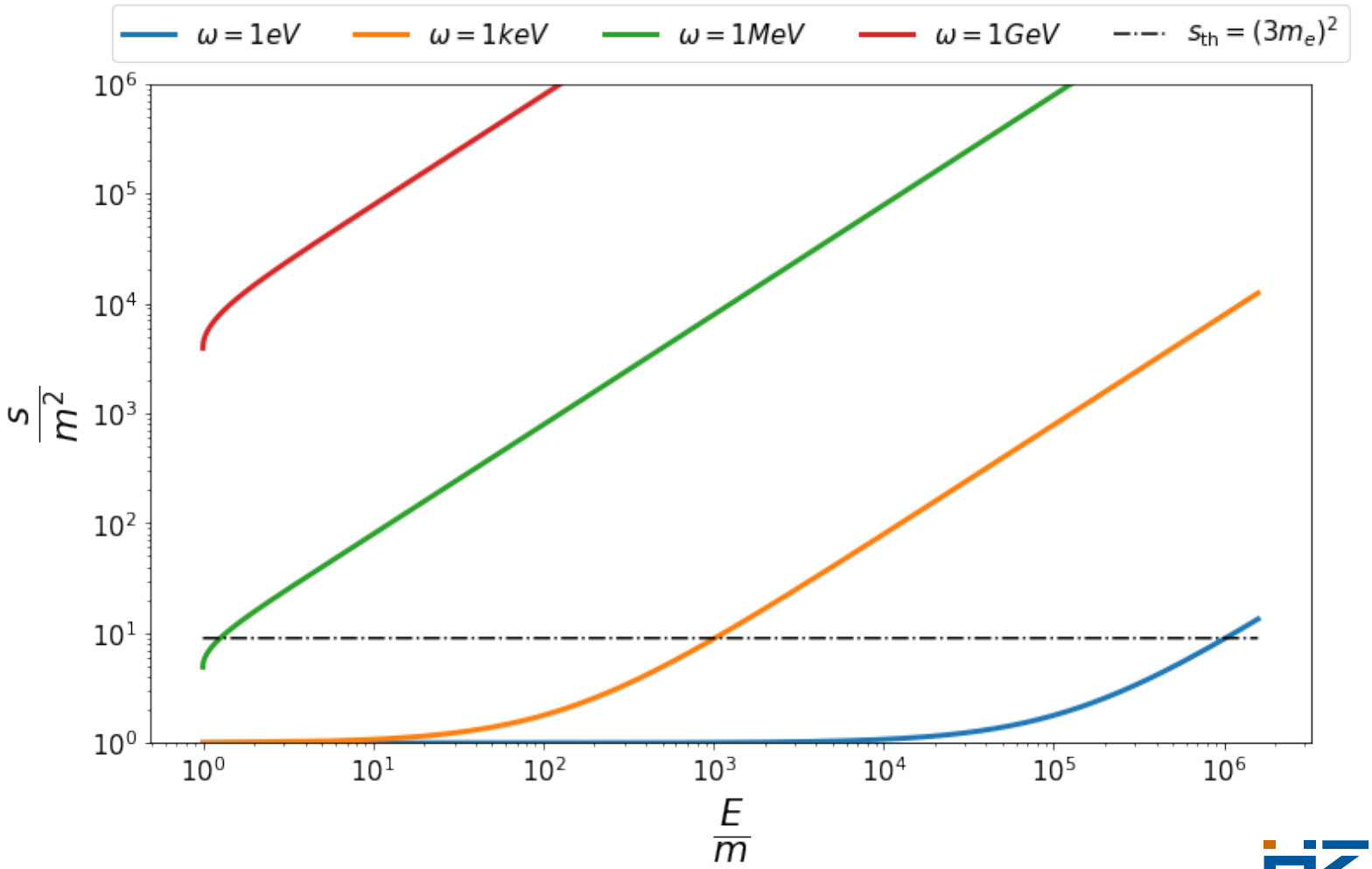


(Hu, Müller, Keitel; 2010)
(Ilderton; 2011)
(King, Ruhl; 2013)
(Dinu, Torgrimsson; 2017)
(King, Fodotov; 2018)
(Mackenroth, Di Piazza; 2018)

Strong-field trident

heads-on collision

$$s = (k + p)^2$$



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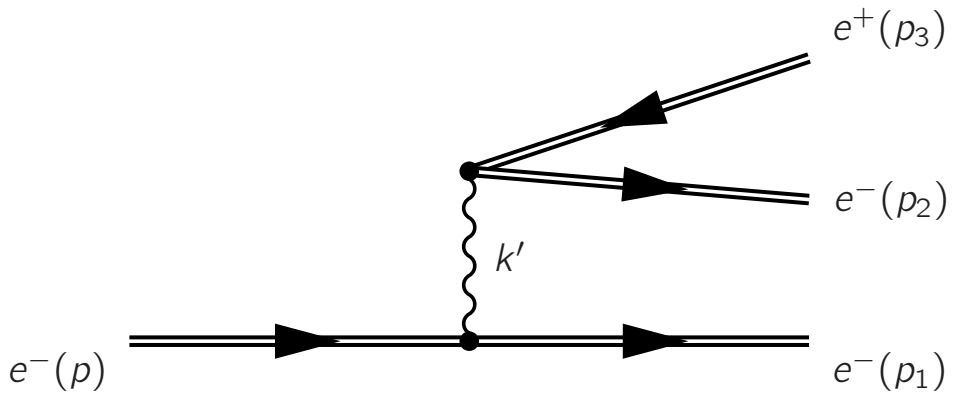
Strong-field trident

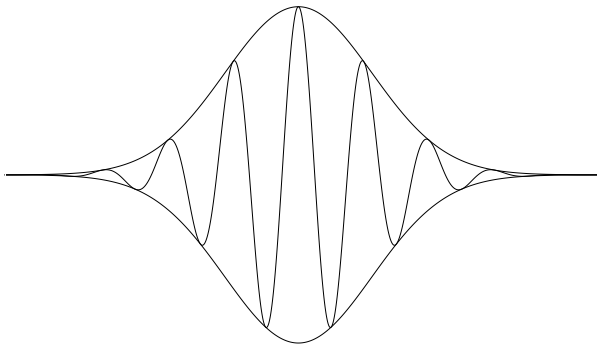
Setup



background field:

$$A^\mu(\varphi) = \cos(\varphi) g(\varphi) a^\mu$$

$$\text{with } a^\mu a_\mu = -\frac{m^2 a_0^2}{e^2}$$

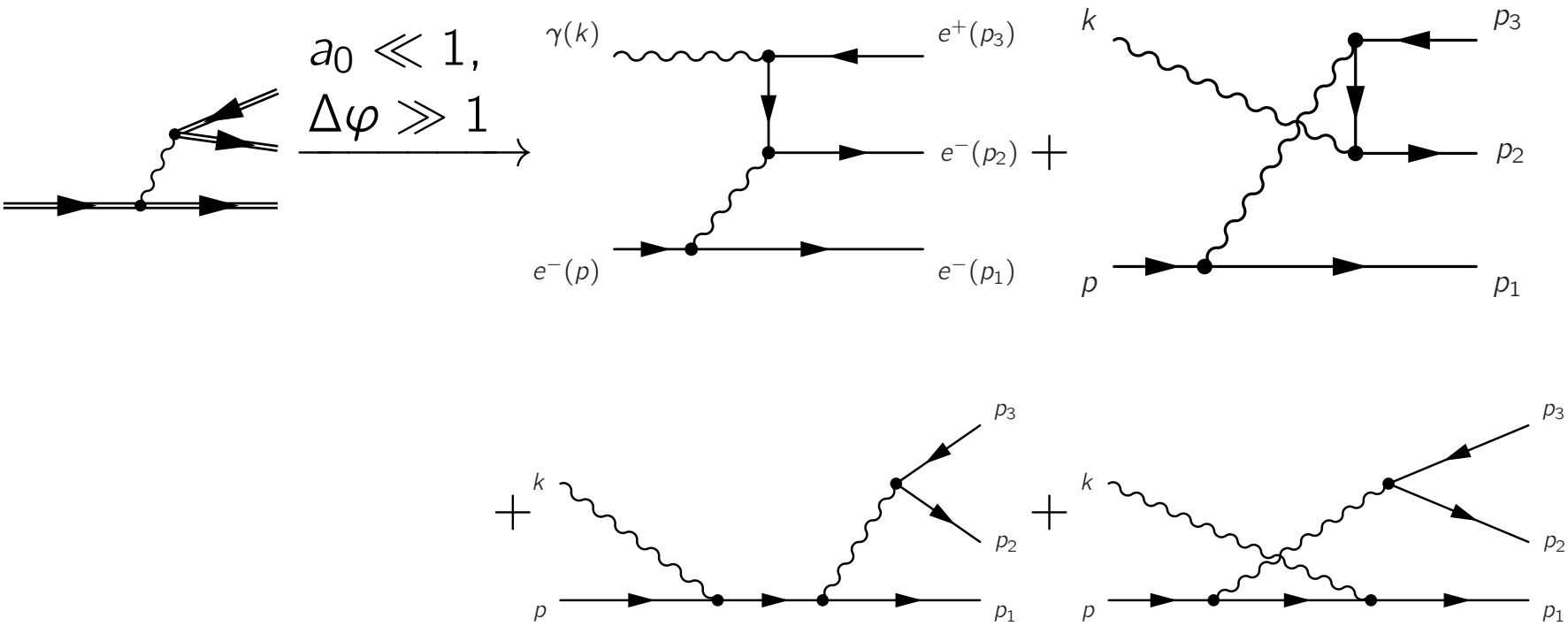


virtual photon:

$$k'^2 = (p - p1 + r_c \cdot k)^2 = (p_2 + p_3 - r_{bw} \cdot k)^2$$

Weak-field limit

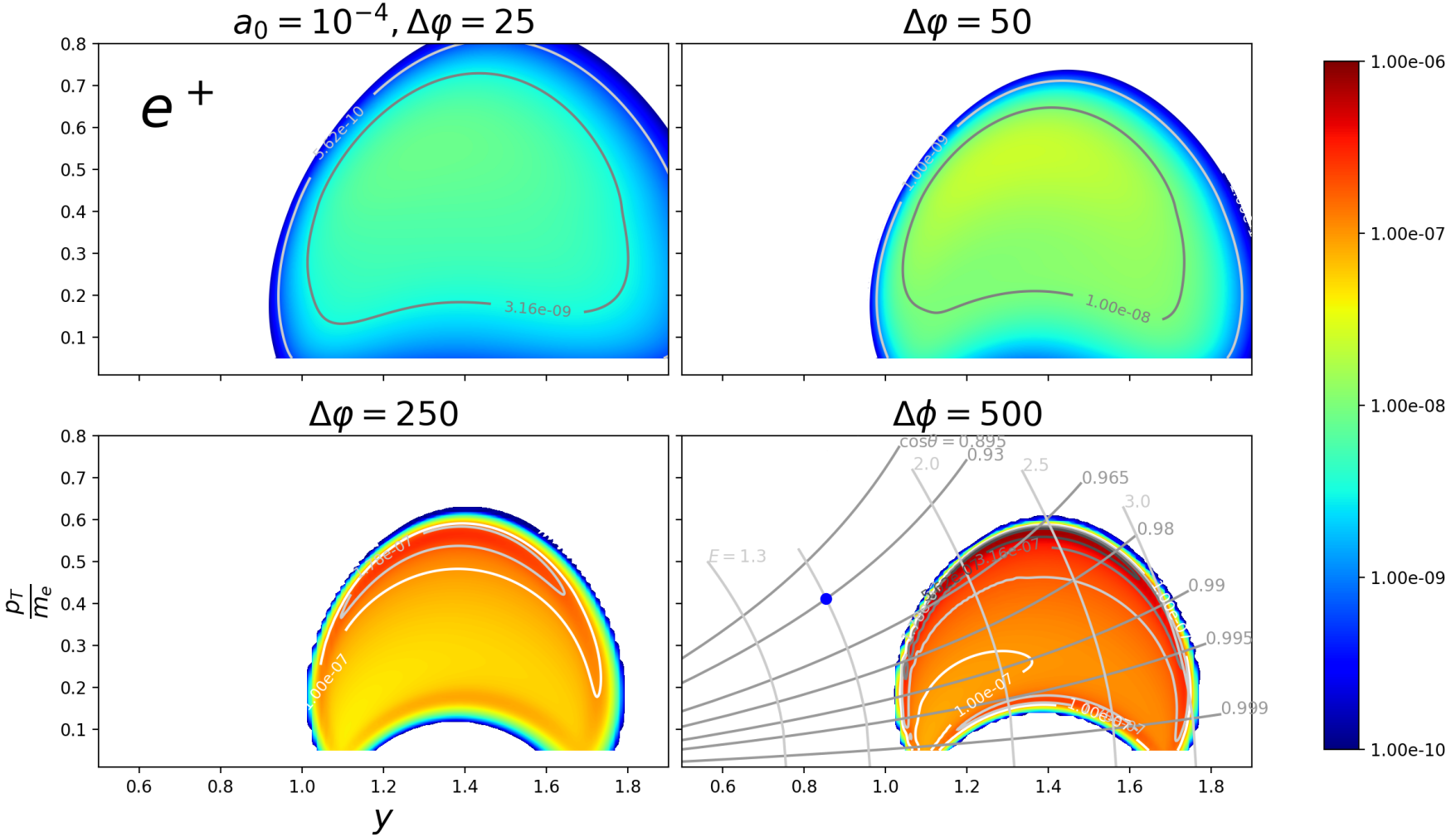
Feynman diagrams: tree-level (Suh, Bethe; 1959), (Mork; 1967), (Haug; 1975), ...



$$- (p_1 \leftrightarrow p_2) + \mathcal{O}(a_0^2)$$

Weak-field limit: e^-_{init} at rest

$\sqrt{s} = 3.353\, m_e$, $(E_1, \cos\theta_1, \phi_1) = (1.5 m_e, 0.95, 0.0)$



$$y = \frac{1}{2} \ln\left(\frac{E + p_z}{E - p_z}\right) \qquad p_T = \sqrt{E^2 - m_e^2}\cos\theta$$

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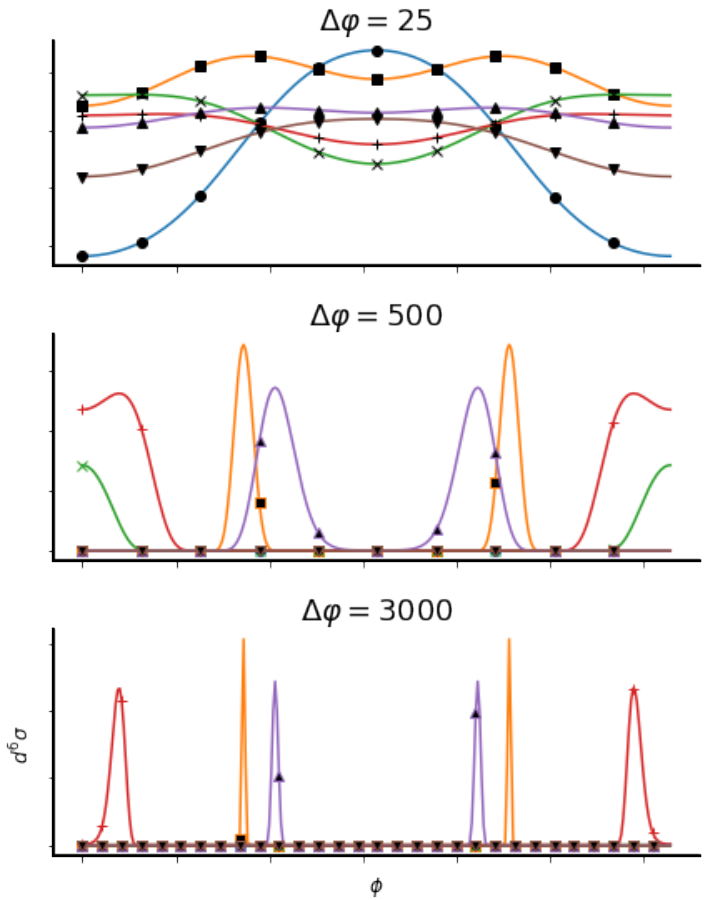
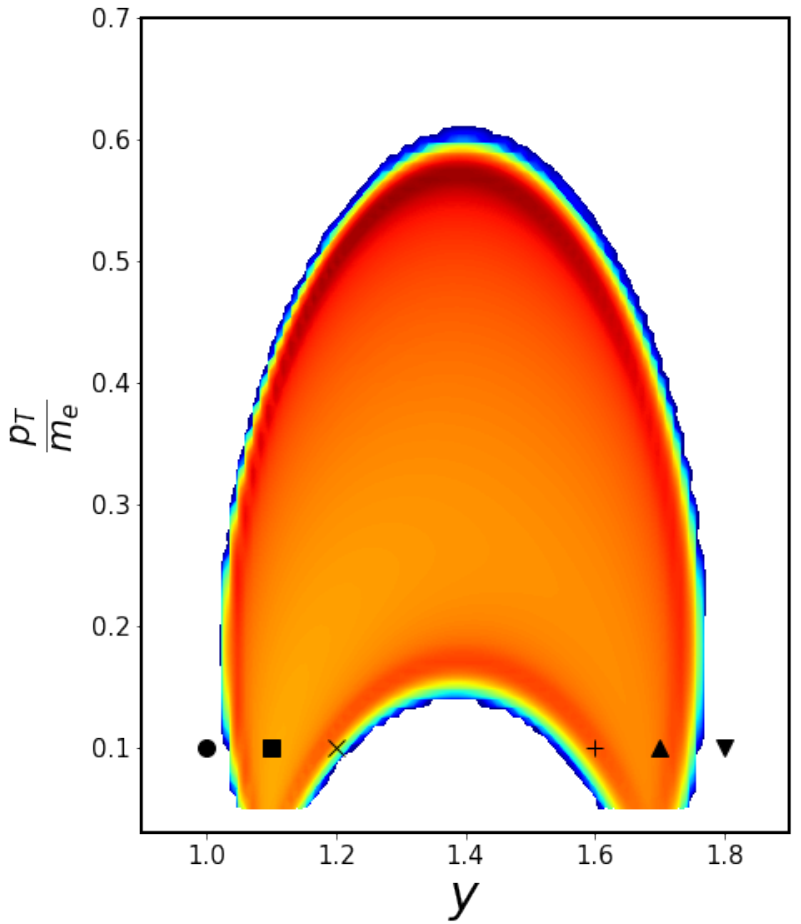
Weak-field limit: e^-_{init} at rest

azimutal distribution positron

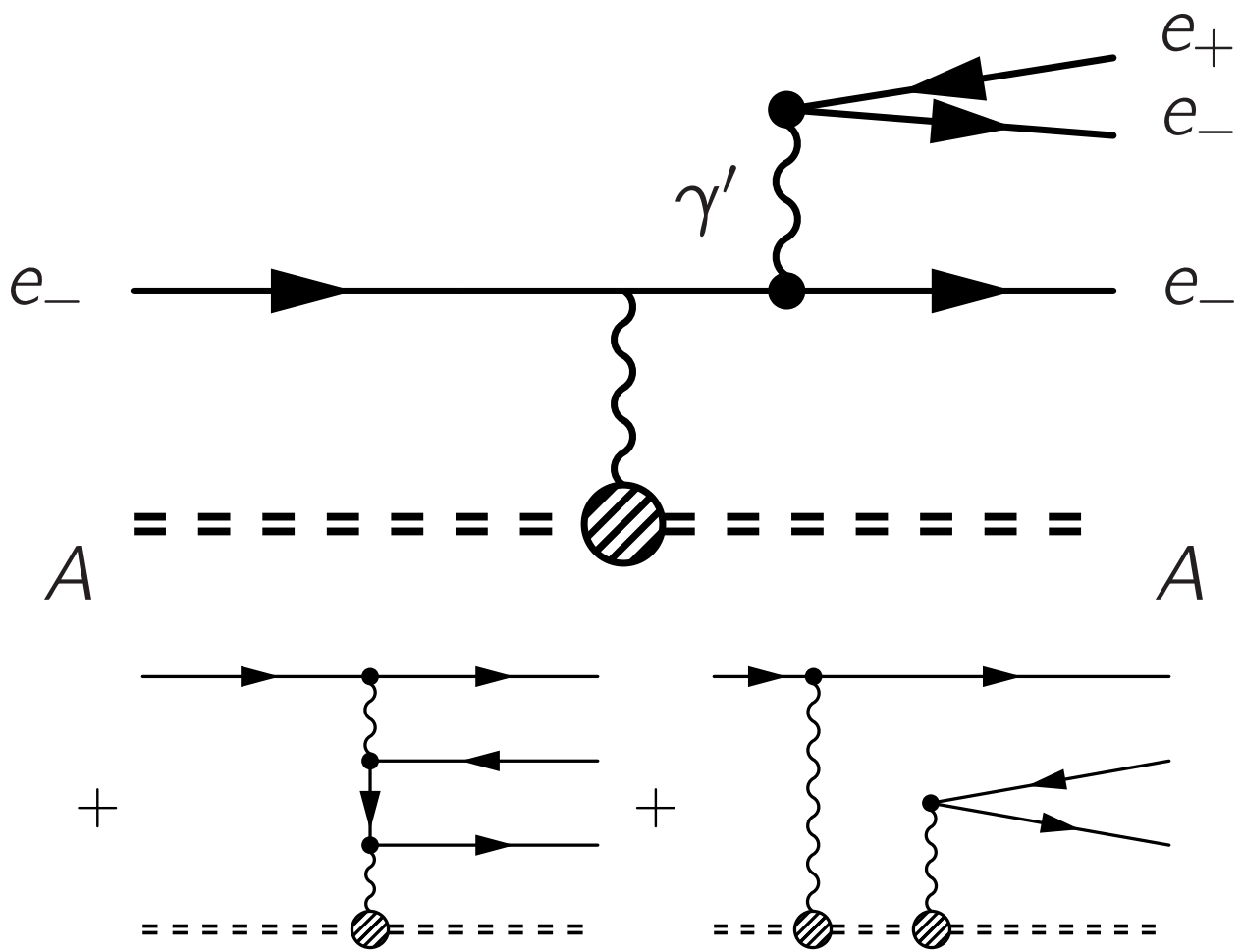




Weak-field limit

Dark photon capability

(Beranek,Merkel,Vanderhaeghen; 2013)



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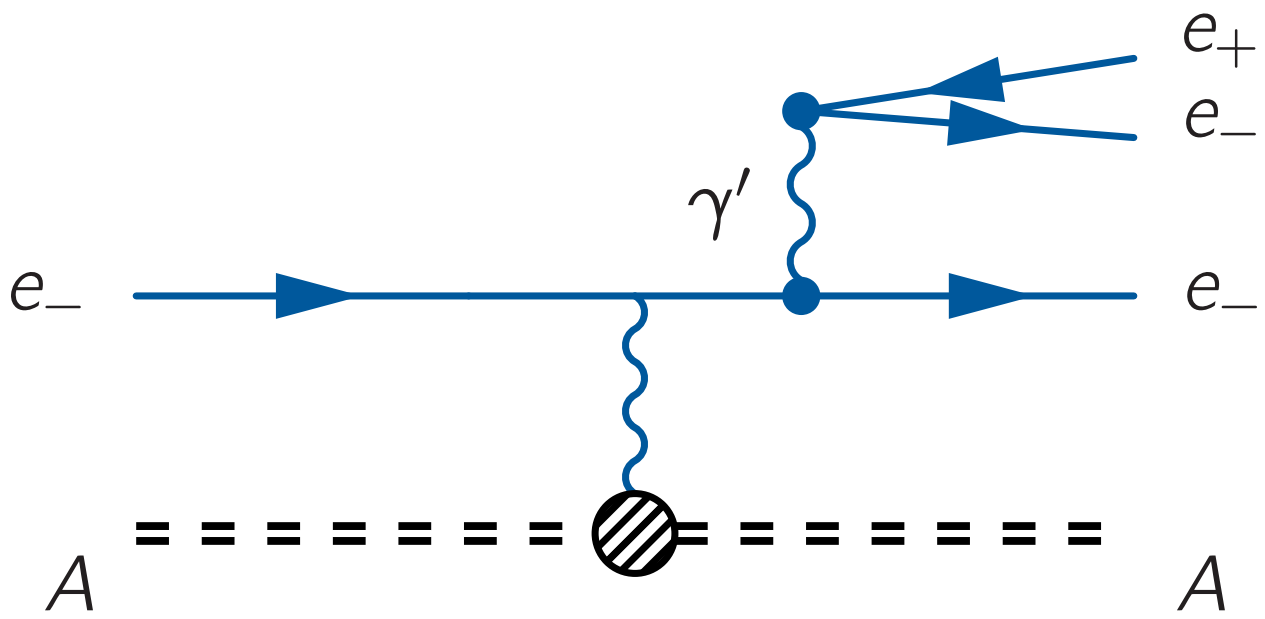
Weak-field limit

Dark photon capability



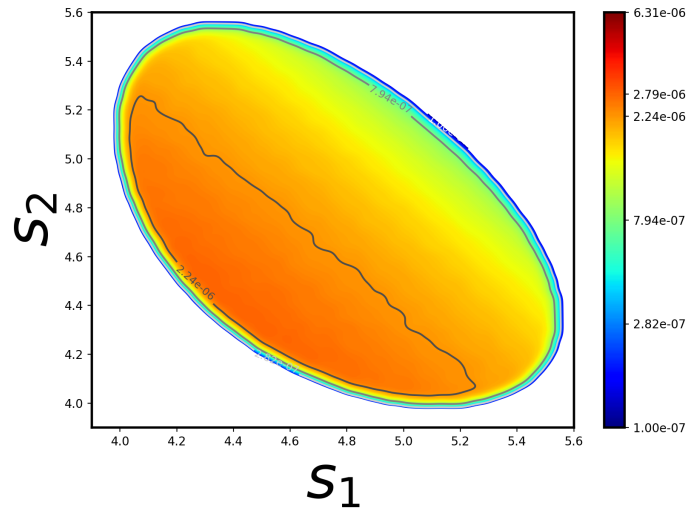
$\rightarrow$ pure QED! (Gakh, Konchatnij, Merenkov; 2015)

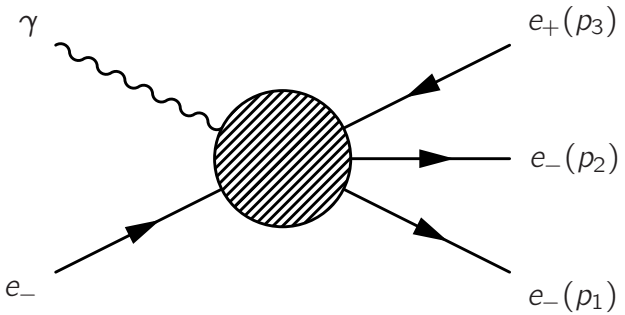
$\rightarrow$ strong-field QED?

Weak-field limit

Invariant mass distribution $\frac{d\sigma}{ds_1\, ds_2}$ $(\sqrt{s} = 3.353\, m_e)$

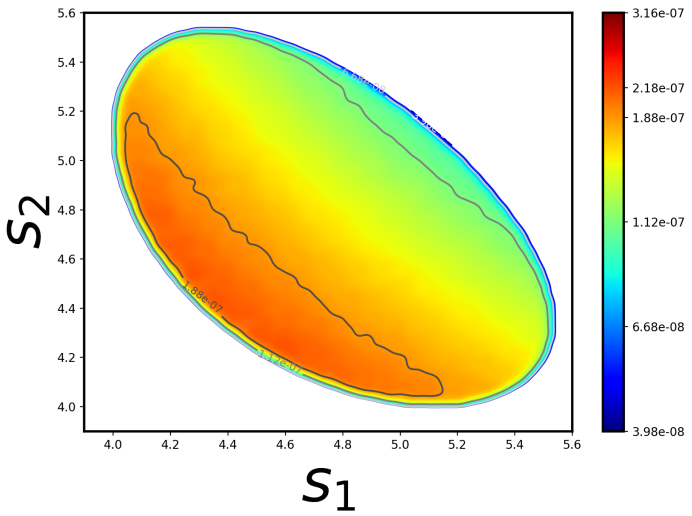
all diagrams



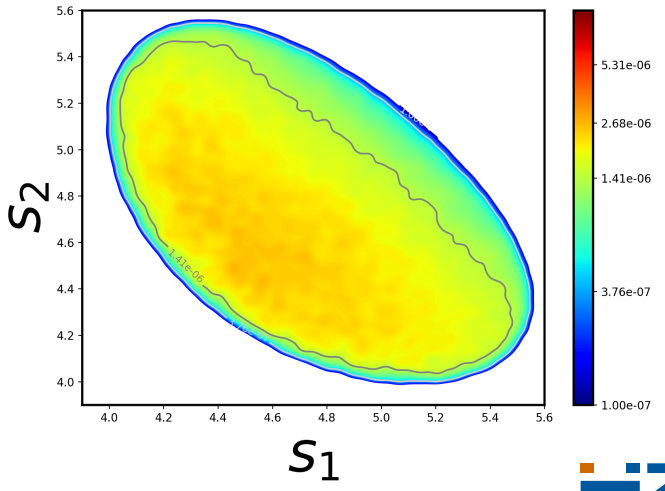


$$s_1 = (p_1 + p_3)^2$$
$$s_2 = (p_2 + p_3)^2$$

Compton



Breit-Wheeler



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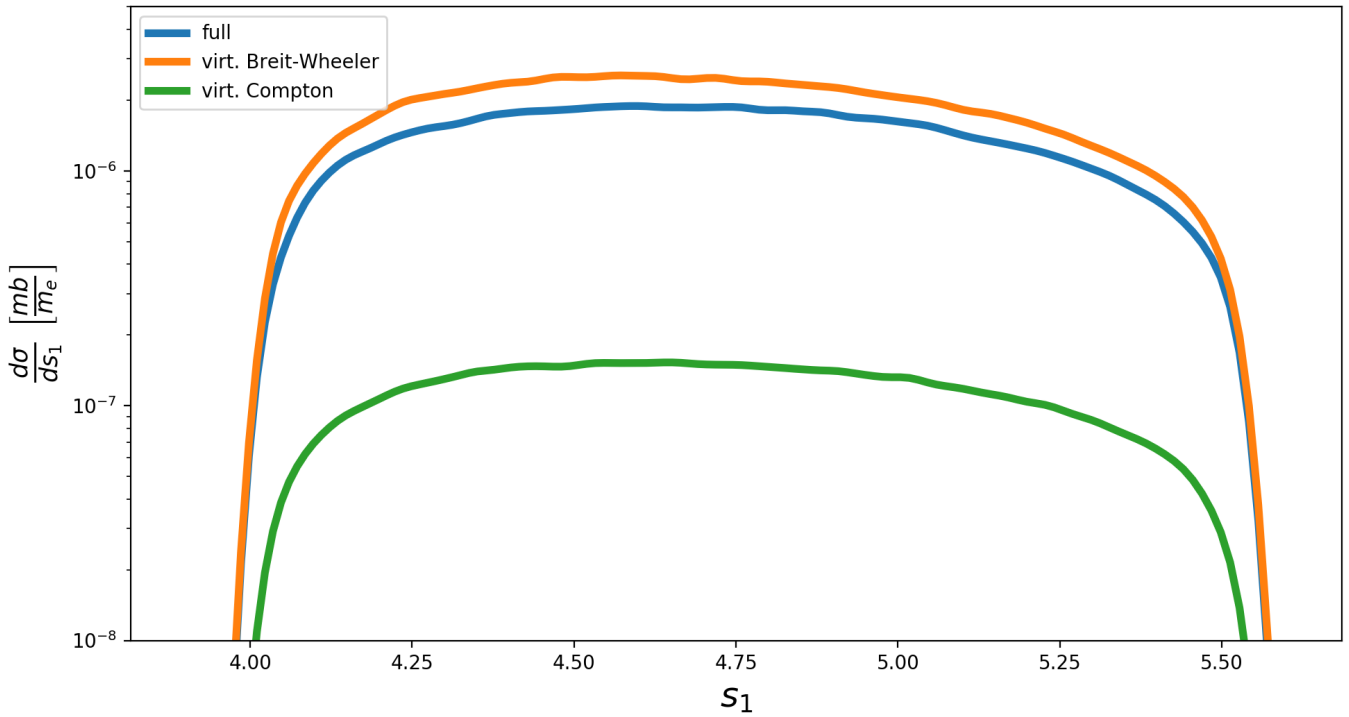
Weak-field limit

Invariant mass distribution $\frac{d\sigma}{ds_1}$ $(\sqrt{s} = 3.353\, m_e)$



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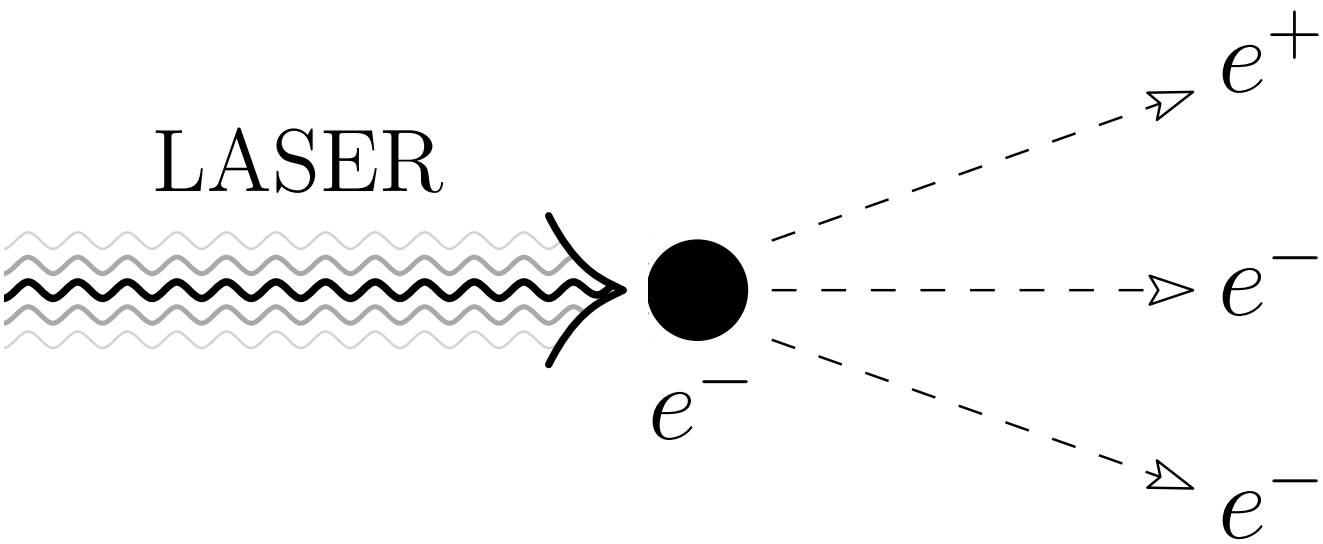
Outlook

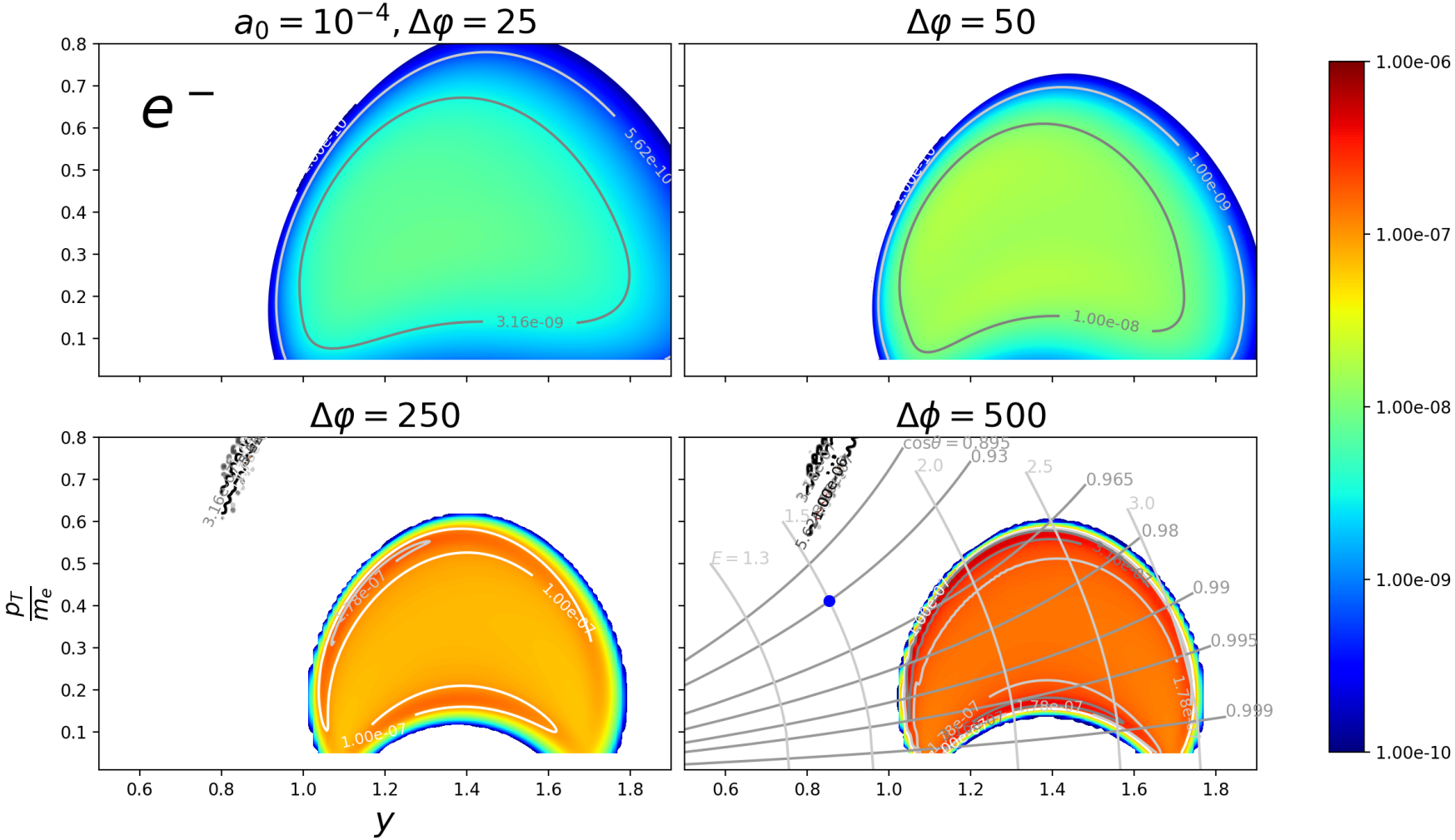
- inclusion of dark photons in weak field & strong field case
- finish numerics of strong field trident:
  - mass and more phase space distributions
  - going to higher a_0
  - ...

Thank you
for your attention.



Backup: Weak-field limit

Partial diagrams: $\sqrt{s} = 3.353\, m_e$ (e^-_{init} at rest, p_1 fix)



$$y = \frac{1}{2} \ln\left(\frac{E + p_z}{E - p_z}\right) \qquad p_T = \sqrt{E^2 - m_e^2} \cos\theta$$