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Laser-assisted processes beyond the Standard Model

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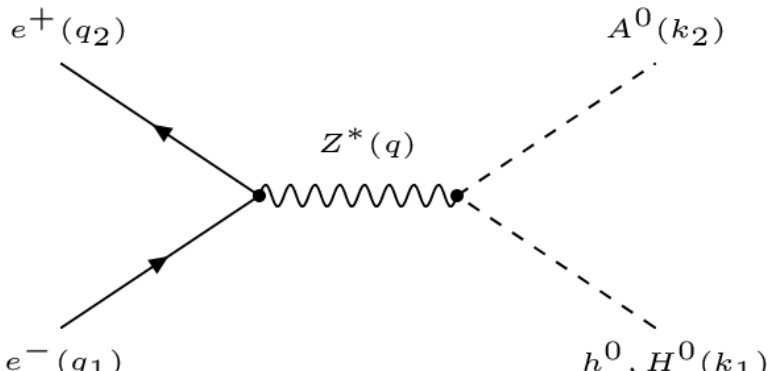
Introduction

- The physics of strong laser field is the general research field of the laser-matter interaction.
- A new physics can be developed from the interaction of intense laser fields with atoms, molecules, and particles.
- How can the behavior and properties of particles change in the presence of an electromagnetic field (EM) ?
- What is the effect of the EM field (provided by a laser) on the evolution of a quantum system ?
- An example of a quantum system :
  Scattering process



Theoretical Calculation

- The scattering matrix element $\mathcal{S}_{fi}$

$$
\begin{aligned}
S_{fi_{(e^+e^-\to A^0\Phi)}} &= -\sin(\beta-\alpha)[\cos(\beta-\alpha)]\frac{-ig}{2C_W}\int d^4x\int d^4y \\
&\times \bar{\psi}_{p_2,s_2}(x)\Big(\gamma_\mu(g_v^e-g_a^e\gamma^5)\Big)\psi_{p_1,s_1}(x)D^{\mu\nu}(x-y) \\
&\times \phi^*_{k_1}(y)\left(\frac{ig\overleftrightarrow{\partial_\nu}}{2C_W}\right)\phi^*_{k_2}(y) \quad \text{for} \quad \Phi = H^0[h^0] \quad (1)
\end{aligned}
$$

- Free Dirac and Klein-Gordon wave function :

$$
\psi_{p_i,s_i}(x) = \frac{u(p_i,s_i)}{\sqrt{2E_iV}}\,e^{-ip_i.x} \qquad \phi_{p_i}(y) = \frac{1}{\sqrt{2E_iV}}e^{-ip_i.y} \qquad (2)
$$

Theoretical Calculation

- Dirac equation in the presence of an EM field :

$$\left[(p_i - eA)^2 - m_e^2 - \frac{ie}{2}F_{\mu\nu}\sigma^{\mu\nu}\right]\psi_{p_i,s_i}(x) = 0 \tag{3}$$

- Dirac-Volkov wave function :

$$\begin{cases} \psi_{p_i,s_i}(x) = \left[1 - \dfrac{e\not{k}\not{A}}{2(k.p_i)}\right]\dfrac{u(p_i,s_i)}{\sqrt{2Q_iV}}\, e^{iS(q_i,s_i)} \\ S(q_i,s_i) = -q_ix + \dfrac{e(a_1.p_i)}{k.p_i}\sin\phi - \dfrac{e(a_2.p_i)}{k.p_i}\cos\phi \end{cases} \tag{4}$$

$$q_i = p_i + \left(\frac{e^2a^2}{2(k.p_i)}\right)k \qquad Q_i = E_i + \left(\frac{e^2a^2}{2(k.p_i)}\right)k^0 \tag{5}$$

Theoretical Calculation

- The quadri-potential $A^\mu(\phi)$ of such a laser wave can be read as follows :

$$A^\mu(\phi) = a_1^\mu \cos\phi + a_2^\mu \sin\phi \qquad ; \qquad \phi = (k.x) \qquad (6)$$

$k = (\omega, 0, 0, \omega)$ is the wave vector of the laser with a photon energy ω which propagates in the z direction, $a_1^\mu = (0, a, 0, 0)$ and $a_2^\mu = (0, 0, a, 0)$ are the quadri-vectors polarization.

$$a_1^2 = a_2^2 = -a^2 = -\left(\varepsilon_0/\omega\right)^2$$

- Where ω is the laser frequency and ε_0 is the laser field amplitude.
- Lorentz gauge condition : $k_\mu A^\mu = 0, \Longrightarrow (k.a_1) = (k.a_2) = 0.$

Theoretical Calculation

- Differential Cross-section :

$$\frac{d\sigma}{d\Omega} = \sum_{n=-\infty}^{+\infty} \frac{1}{|J_{inc}|} |\overline{S_{fi}^{n}}|^2 \int \frac{d^3p_3}{(2\pi)^3 E_Z} \int \frac{d^3p_4}{(2\pi)^3 E_H} \tag{7}$$

Where

$$|J_{inc}| = (\sqrt{(q_1 q_2)^2 - m_e^{*4}}/Q_1 Q_2 V) \tag{8}$$

and

$$m_e^* = \sqrt{m_e^2 + e^2 a^2} \tag{9}$$

- Total Cross-section :

The total cross section is obtained by performing a numerical integration over the solid angle $d\Omega = \sin(\theta) d\theta d\phi$.

Results and discussion

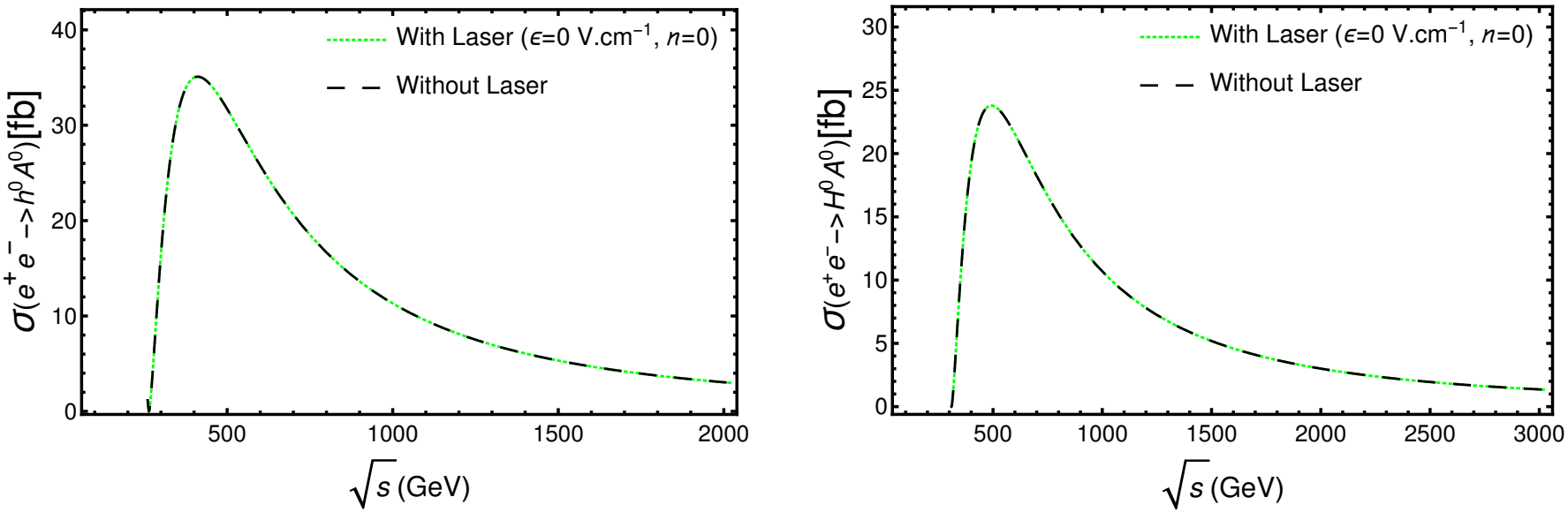
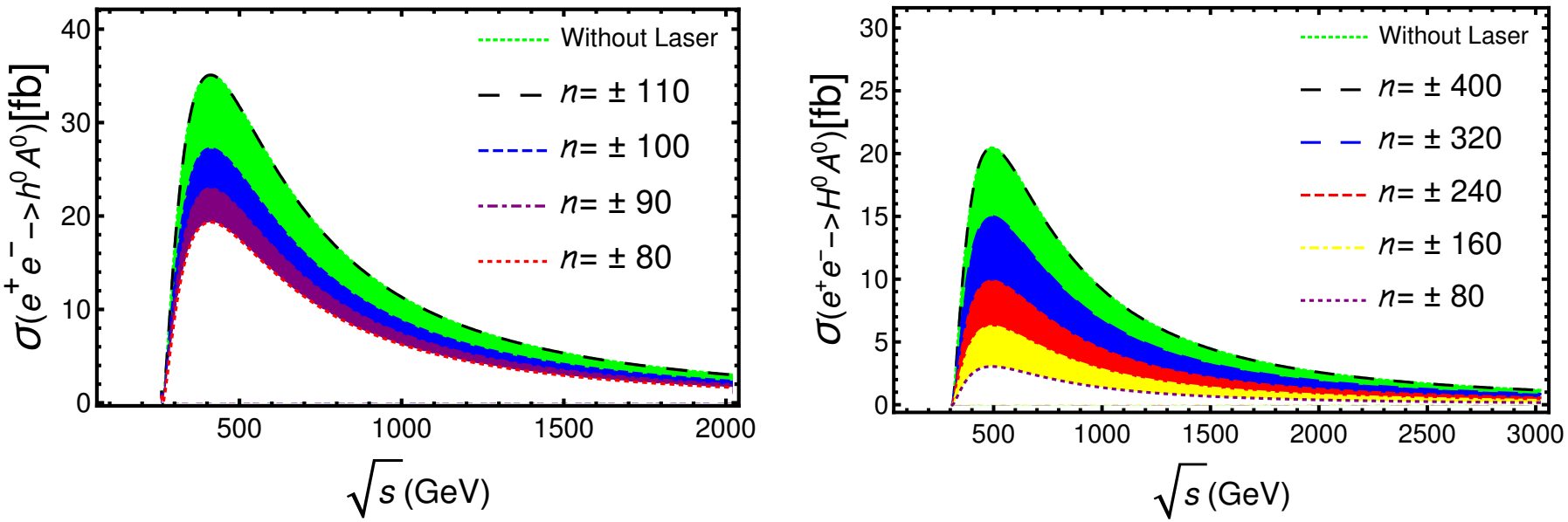


Figure – Laser-assisted TCS of the process $e^+e^- \to h^0A^0, H^0A^0$ as a function of $\sqrt{s}$ for different numbers of exchanged photons.

Results and discussion



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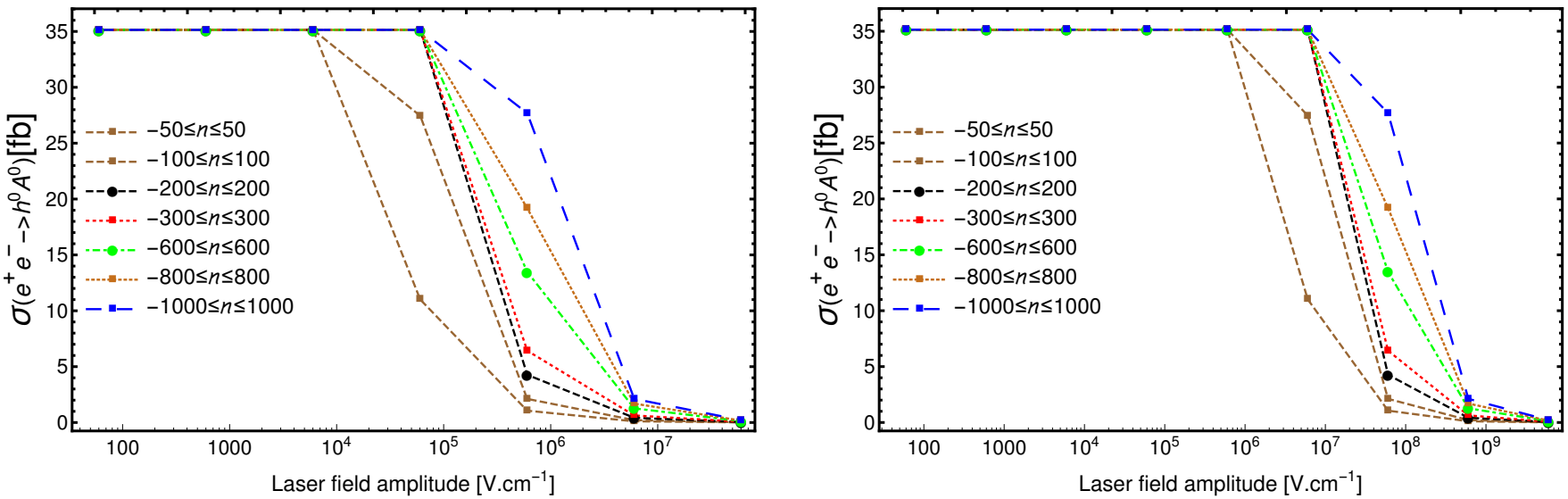

Figure – Laser-assisted TCS of the process $e^+e^- \to h^0A^0$ as a function of laser field amplitude for different numbers of exchanged photons.

Results and discussion

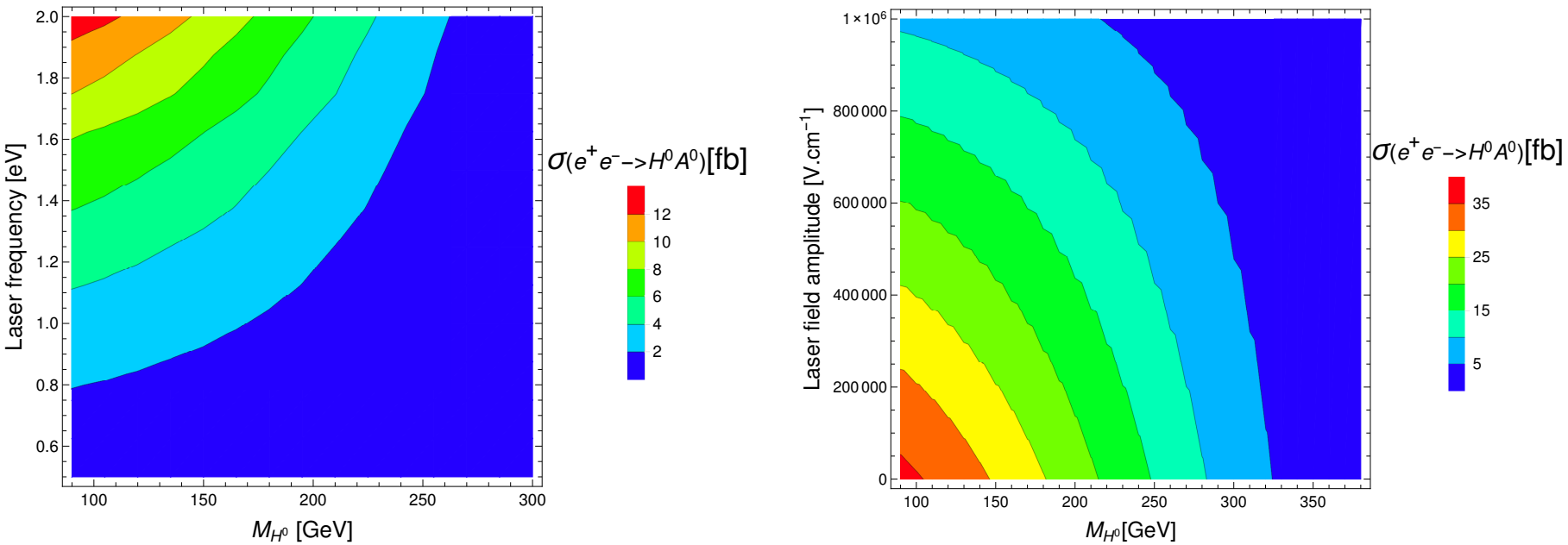

Figure – Laser-assisted TCS of the process $e^+e^- \to H^0A^0$ as a function of m_{H^0} and the laser field frequency (left panel) or laser field amplitude (right panel).

Conclusion

- The Total cross section of the Higgs boson production is decreased by the circularly polarized laser field.
- The laser field has an important impact on the properties of the particles and their interactions.

Limites : Expérimental ! !

- These results require an experimental investigation to confirm them in order to meet the demands of the scientific community in the future, in parallel with the remarkable development of the laser technology.
- It was time to benefit from the power of the laser and to consider this technology as an interesting solution.


THANK YOU
FOR YOUR
ATTENTION