Resummation effects in HECO pair production at the LHC: UFO implementation

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One considers the electromagnetic interactions of a **H**igh **E**lectrically **C**harged **O**bject assumed to be a spin-1/2 Dirac fermion, $\psi(x)$, which couples to a massless photon $A_\mu(x)$ with a charge $g = ne$ ($n \in \mathbb{Z}^+$) being e the electron charge. Due to the *large coupling* the perturbation theory breaks down → **Resummation needed**

Resummation

γ-only exchange

Running mass: $\mathcal{M}(\Lambda) = \Lambda \exp\left(-\frac{2\pi}{\alpha^\star}(Z^\star - 1)\right)$

HECO-fermion propagator: $G^{\text{eff}} = i\frac{\not{p}+\mathcal{M}(\Lambda)}{p^2-\mathcal{M}(\Lambda)^2}$

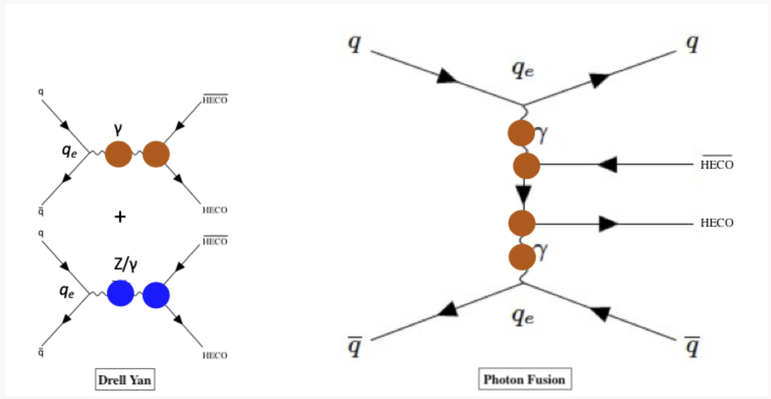
Photon propagator: $\Delta^{\text{eff}}_{\mu\nu} = \frac{-i}{q^2}\left(\eta_{\mu\nu} + \frac{\omega^\star}{1+\omega^\star}\frac{q_\mu q_\nu}{q^2}\right)$

Photon-HECO vertex: $\Gamma^{\text{eff}}_\mu = g\, Z^\star \gamma_\mu$

with $\hat{\alpha}^\star$ is the rescaled electric coupling $\hat{\alpha}^\star = \frac{g^2/4\pi}{1+\hat{\omega}^\star}$, $Z^\star = 1.477$

the wavefunction renormalization and $\omega^\star = \frac{4}{3}\left(1 - \frac{1}{Z^\star}\right) \simeq 0.431$

Fixed-point solution of Dyson–Schwinger equations ($n \geq 11$)



Z^0 inclusion

Same procedure as for photon with the replacement:

$g^2 \to \hat{g}^2 \equiv g^2 + 3g'^2/4$ where g' is the Z_0-HECO coupling

$\mathcal{M}(\Lambda) = \Lambda \exp\left(-\frac{2\pi}{\hat{\alpha}^\star}(\hat{Z}^\star - 1)\right)$

$\hat{Z}^\star = \hat{Z}_+ = \frac{2}{9}(3+\eta)\left(1 + \sqrt{1 - \frac{9\eta}{(3+\eta)^2}}\right)$

$\hat{\omega}^\star = \frac{4}{3}\eta\left(1 - \frac{1}{\hat{Z}^\star}\right)$ with $\eta \equiv g^2/\hat{g}^2 < 1$.

UFO Models

Two different UFO models have been created:

1. γ-only;
2. Z^0 inclusion.

New *input* parameters:

- the multiplicity n of the HECO charge $g = ne$
- the cut-off Λ

Validation

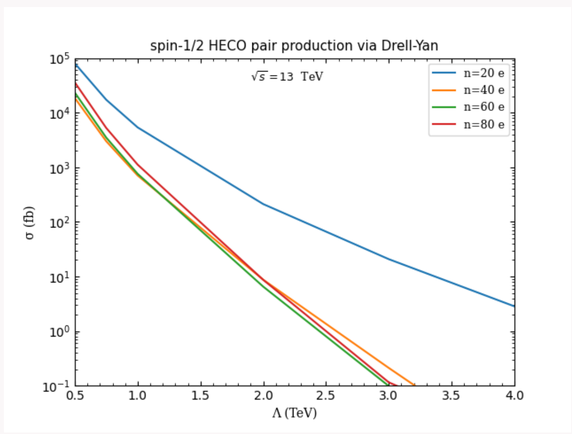
$u\bar{u} \to \gamma/Z_0 \to \text{HECO}\,\overline{\text{HECO}}$ with resumm. @ $\sqrt{s} = 13$ TeV $\Lambda = 2$ TeV, NOPDF option			
n	$\sigma_{\text{MadGraph5}}$ (pb)	$\sigma_{\text{Mathematica}}$ (pb)	UFO/Theory
20	0.0659	0.0655	1.006
60	0.5919	0.5886	1.005
100	1.6460	1.6345	1.007
140	3.2251	3.2035	1.006
180	5.3224	5.2955	1.005

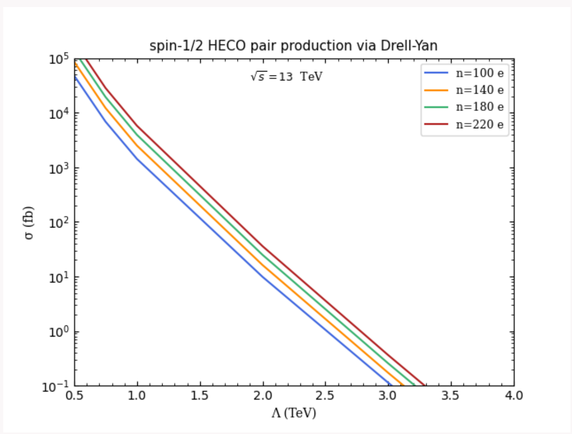
Impact on Production Cross Sections

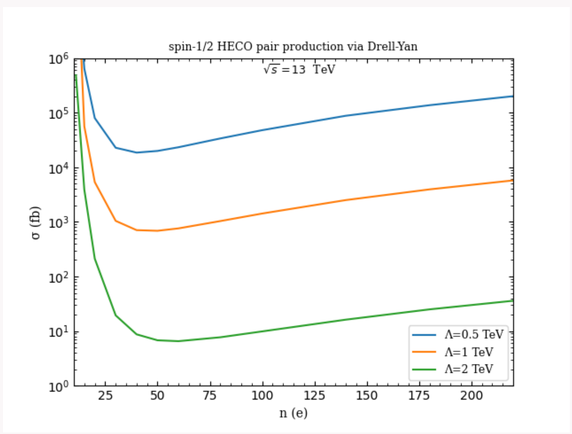
Drell–Yan $pp \to \gamma/Z_0 \to \text{HECO}\,\overline{\text{HECO}}$ @ $\sqrt{s} = 13$ TeV, $\Lambda = 2$ TeV, NNPDF2.3			
n	σ_{resum} (fb)	$\sigma_{\text{tree-level}}$ (fb)	M_{HECO} (TeV)
20	$2.118{\cdot}10^2$	$1.014{\cdot}10^2$	0.798
60	6.527	3.367	1.780
100	9.835	4.722	1.924
140	$1.6245{\cdot}10^1$	7.752	1.961
180	$2.492{\cdot}10^1$	$1.195{\cdot}10^1$	1.976
220	$3.594{\cdot}10^1$	$1.722{\cdot}10^1$	1.984

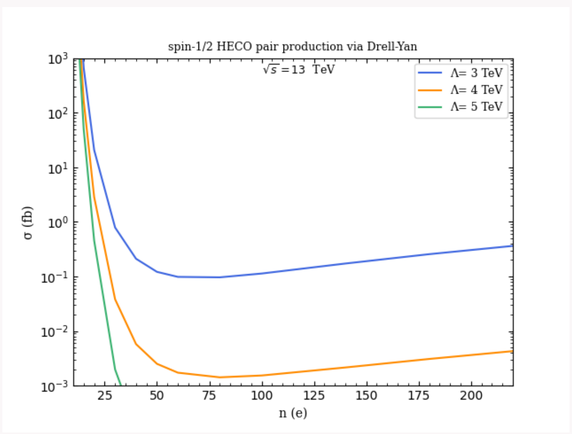
Photon fusion $\gamma\gamma \to \text{HECO}\,\overline{\text{HECO}}$ @ $\sqrt{s} = 13$ TeV, $\Lambda = 2$ TeV, LUXqed17			
n	σ_{resum} (fb)	$\sigma_{\text{tree-level}}$ (fb)	M_{HECO} (TeV)
20	$6.271 \cdot 10^4$	$1.321 \cdot 10^4$	0.507
60	$4.025{\cdot}10^3$	$8.466 \cdot 10^2$	1.717
100	$1.372{\cdot}10^4$	$2.895 \cdot 10^3$	1.893
140	$4.170{\cdot}10^4$	$8.753{\cdot}10^3$	1.945
180	$1.030{\cdot}10^5$	$2.175{\cdot}10^4$	1.966
220	$1.531 \cdot 10^5$	$4.612 \cdot 10^4$	1.977

Drell-Yan Mechanism

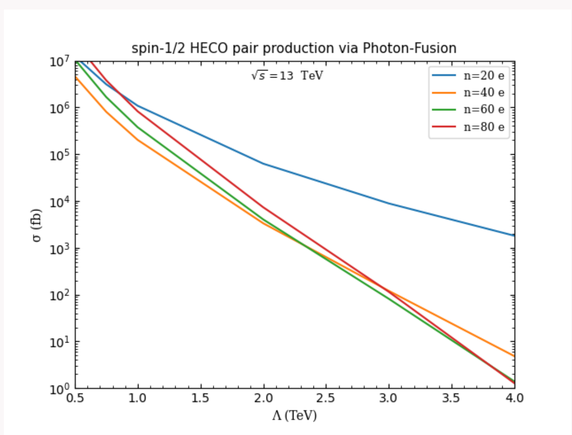


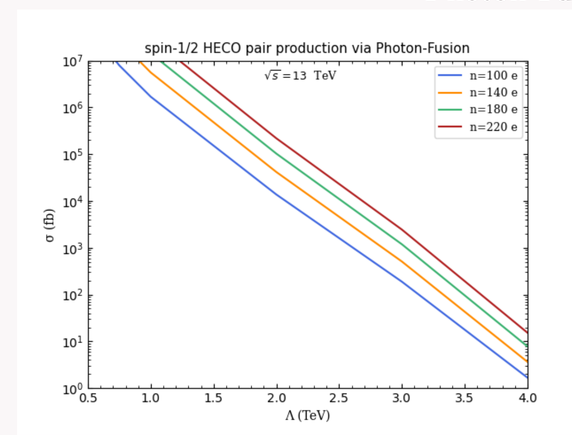


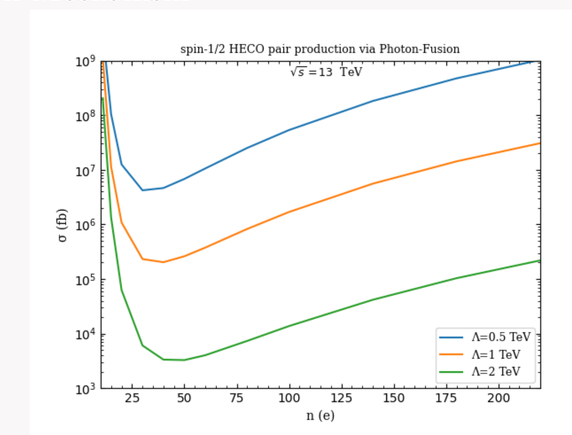


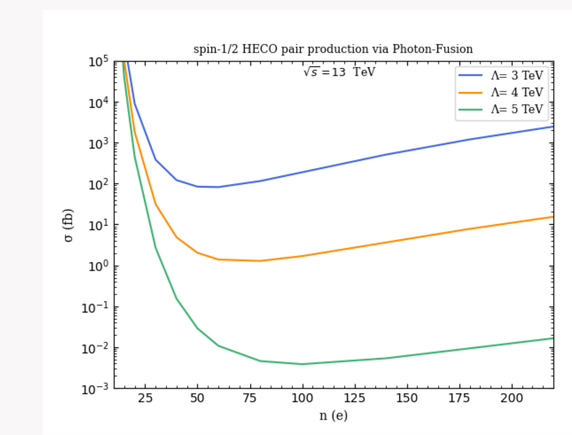


Photon-Fusion Mechanism









Conclusion

Following the resummation, an improvement in the cross section values and more reliable results have been achieved compared to those obtained at the tree-level.

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[1] J. Alexandre and N. E. Mavromatos, *Weak-U(1) × strong-U(1) effective gauge field theories and electron-monopole scattering*, Phys. Rev. D **100**, no.9, 096005 (2019)

[2] B. Acharya et al. *Search for highly-ionizing particles in pp collisions at the LHC's Run-1 using the prototype MoEDAL detector*, Eur. Phys. J. C 82, 694 (2022)

[3] J. Alexandre, N.E. Mavromatos, V.A. Mitsou, E. Musumeci, *to appear*

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