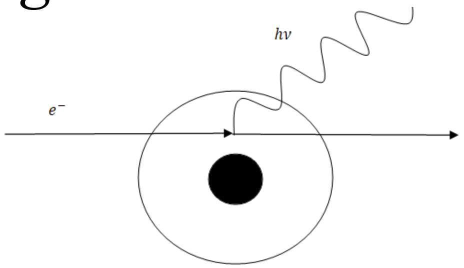
Neutral bremsstrahlung in Xenon

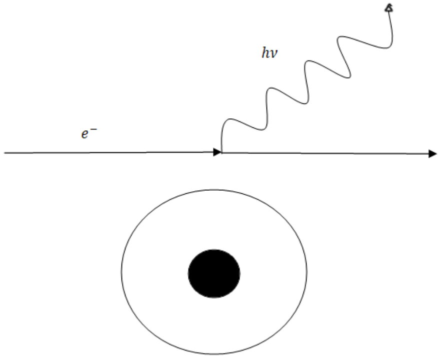
INTRODUCTION

-Ordinary bremsstrahlung is the photon emission by an electron interacting with the nucleus



Bremsstrahlung

- Neutral bremsstrahlung (NBS) is the emission of photons by the electrons when interacting with dipole field of the atom



Neutral Bremsstrahlung

Introduction

-This radiation should exist independently of the applied electrical field in a gaseous TPC

-This could be an explanation for the photon emission in gaseous TPCs below the EL threshold region

-This is precisely the issue we tackle here

THEORY OF NBS

-In order to calculate the Yield we need several ingredients

$$\left(\frac{Y_{EL}}{N}\right)_{NBrS} = \frac{dN_{ph}}{dx\ N\ N_e\ dV} = \frac{1}{\upsilon_d\ N}\int_{\lambda_1}^{\lambda_2}\frac{dI_{ph}(\lambda)}{d\lambda}\ d\lambda = \int_{\lambda_1}^{\lambda_2}\int_{h\nu}^{\infty}\frac{\upsilon_e}{\upsilon_d}\frac{d\sigma}{d\nu}\frac{d\nu}{d\lambda}f(E)\ dE\ d\lambda$$

-Both the energy distribution and the drift velocity can be obtained through MC methods in Pyboltz

-We must find an analytical expression for dσ/dv

Theory of NBS

-Assume an electron with energy Eb, momentum kb and wavefunction φb(r) undergoes a transition to a new state φa(r) with energy Ea and momentum ka

$$h\nu = E_b - E_a = \frac{\hbar}{2m}(k_b^2 - k_a^2)$$

-Energy radiated by unit of frequency and emission cross section

$$dS_\nu = \frac{8\pi e^2 \nu^4 k_b m}{3\hbar^2 c^3}|M|^2 d(h\nu) \longrightarrow \frac{d\sigma_{nu}}{d\nu} = \frac{1}{\nu\nu}\frac{dS_\nu}{d(h\nu)} = \frac{8\pi e^2 \nu^3 k_b m^2}{3\hbar^3 c^3 k_a}|M|^2 \text{ with } M = < \phi_a|r|\phi_b >$$

-To calculate M, we would need to perform the integrals over the wavefunctions

$$|M|^2 = (4\pi)^3 \sum_{l=0}^{\infty} l\left[\left|\int_0^\infty f_b^{l-1}(r) f_a^l(r)\,dr\right|^2 + \left|\int_0^\infty f_a^{l-1}(r) f_b^l(r)\,dr\right|^2\right]$$

-Instead, we can resort to the partial waves method and use some approximations to avoid doing that

$$f(\theta) = \sum_{l=0}^{\infty}(2l+1)a_l(k)P_l(\cos\theta)$$

Theory of NBS

-If we stay at low energies, we don't need to consider partial waves above the incident S wave and the scattered P wave (l=0 and l=1)

-All but the functions f0 and f1 in the integral can be ignored and those two can be replaced

$$f^{0} = k^{-1}\sin(kr + \eta_0)$$

$$f^{-1} = k^{-1}\left(\frac{\sin kr}{kr} - \cos kr\right) \longrightarrow M^{\pm}(0, k_b^2|1, k_a^2) = \frac{1}{2}k_a sin\delta_0$$

-This allows us to quickly compute M

$$|M|^2 = \frac{64\pi^2}{k_b^2 - k_a^2}[k_a^2 q_0(E_b) + k_b^2 q_0(E_a)] \qquad q_{0(E)} = \frac{4\pi}{k^2}\sin^2\eta_0(k)$$

-And produce a final result

$$\left(\frac{d\sigma}{d\nu}\right)_{NBrS,el} = \frac{8}{3}\frac{r_e}{c}\frac{1}{h\nu}\left(\frac{E-h\nu}{E}\right)^{1/2} \times [(E-h\nu)\sigma_{el}(E) + E\sigma_{el}(E-h\nu)]$$

Simulations

- In order to get the yield we need to numerically solve

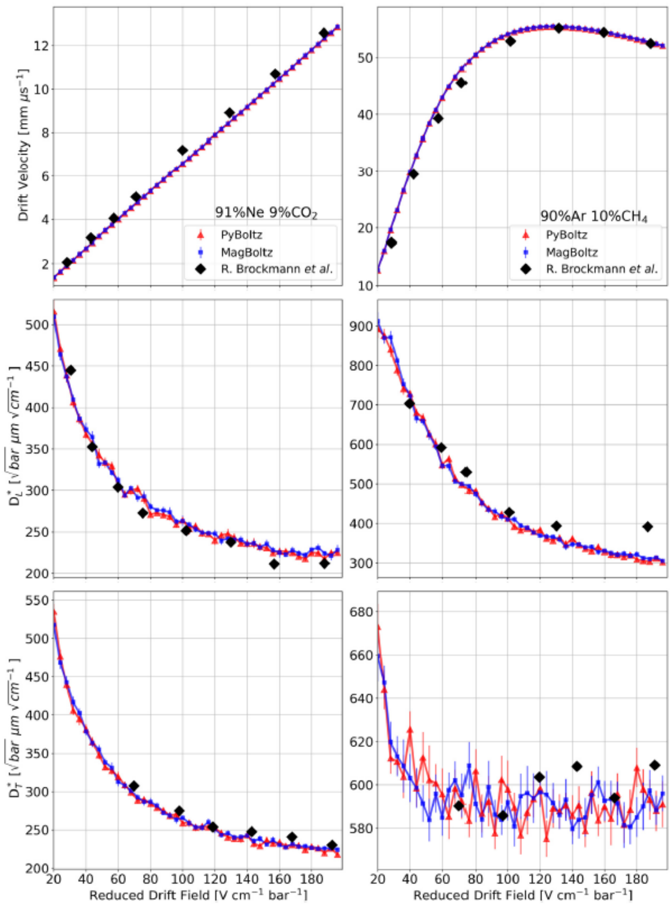
$$\left(\frac{Y_{EL}}{N}\right)_{NBrS} = \frac{dN_{ph}}{dx\ N\ N_e\ dV} = \frac{1}{\upsilon_d\ N}\int_{\lambda_1}^{\lambda_2} \frac{dI_{ph}(\lambda)}{d\lambda}\ d\lambda = \int_{\lambda_1}^{\lambda_2}\int_{h\nu}^{\infty} \frac{\upsilon_e}{\upsilon_d}\frac{d\sigma}{d\nu}\frac{d\nu}{d\lambda} f(E)\ dE\ d\lambda$$

-For that, we need the energy distribution and drift velocity for each electrical field

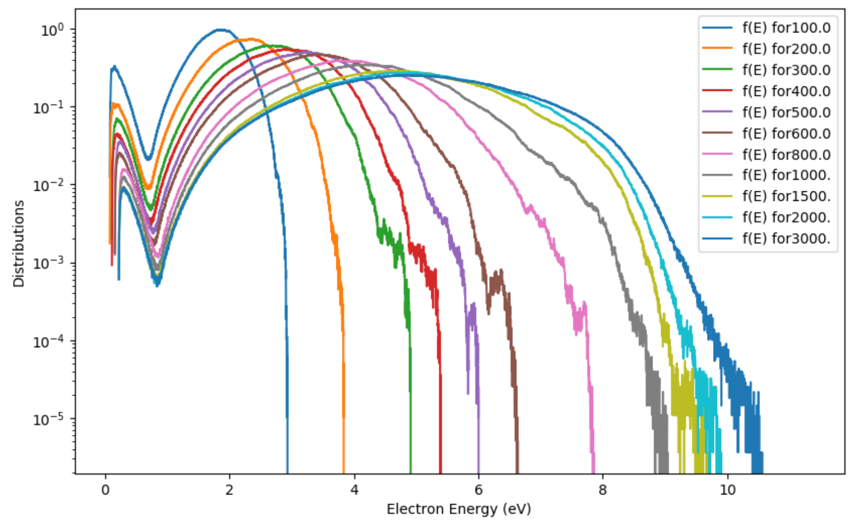
-We get those from PyBoltz

Simulations

-PyBoltz is a refactorization of Magboltz in Python



-We run a modified version

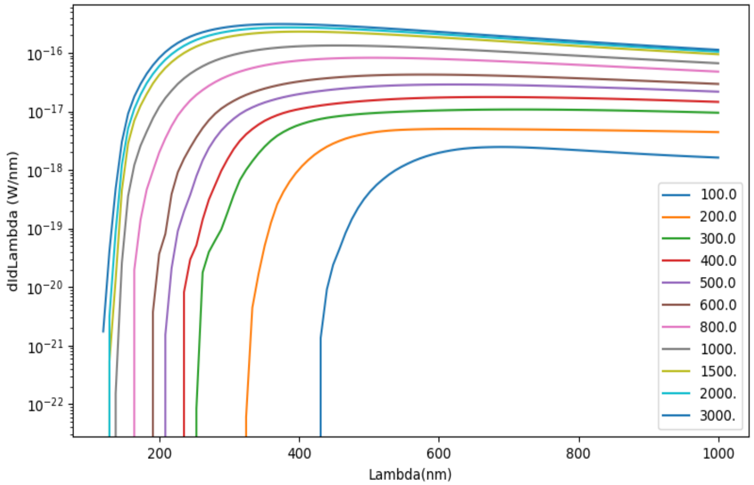


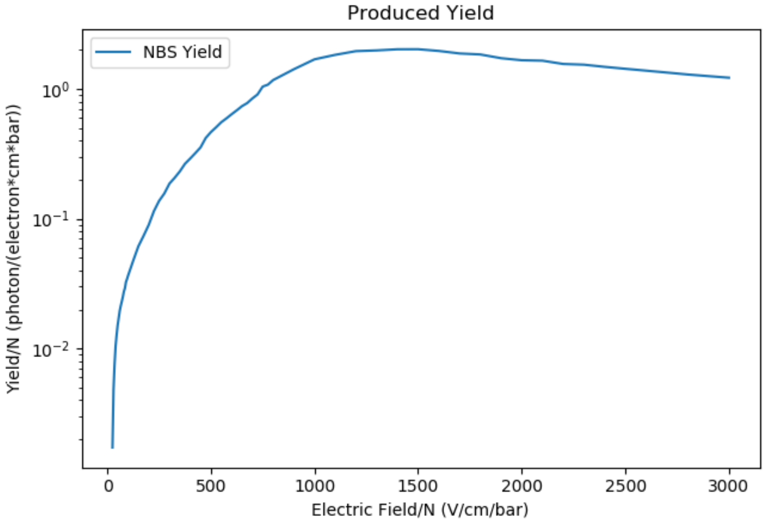
-Check Austin's talk at Tuesday!

SIMULATIONS

- Computing the two integrals we can get the power spectra and the final yield

$$\frac{dI_{ph}(\lambda)}{d\lambda} = \frac{dN_{ph}}{dt\ N_e\ dV\ d\lambda} = N\int_{h\nu}^{\infty} \upsilon_e \frac{d\sigma}{d\nu}\frac{d\nu}{d\lambda} f(E)\ dE \qquad \left(\frac{Y_{EL}}{N}\right)_{NBrS} = \frac{dN_{ph}}{dx\ N\ N_e\ dV} = \frac{1}{\upsilon_d\ N}\int_{\lambda_1}^{\lambda_2} \frac{dI_{ph}(\lambda)}{d\lambda}\ d\lambda$$

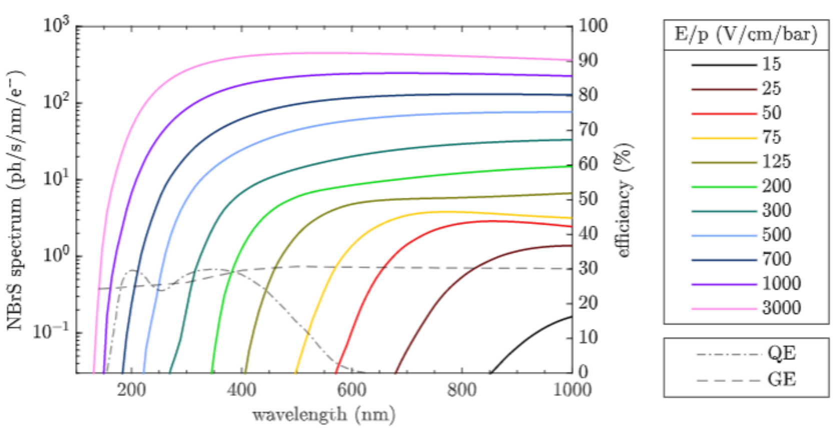


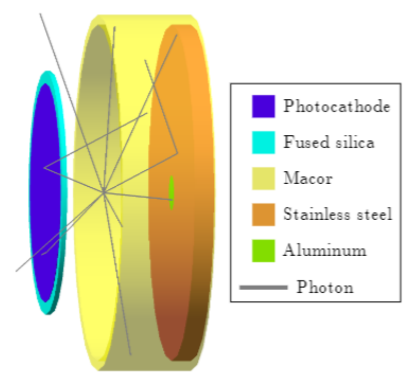


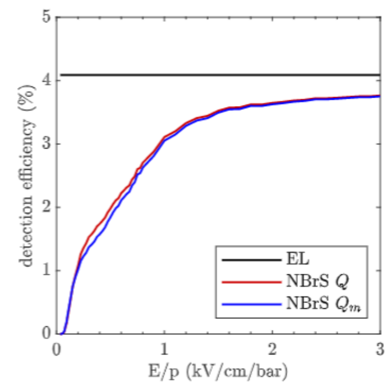
SIMULATIONS

-To be able to get the number of measured photons, a correction by QE and GE is needed

$$< QE \cdot GE > (E) = \frac{\int_{\lambda_1}^{\lambda_2} QE(E)GE(E)\frac{dI_{ph}(\lambda)}{d\lambda}}{\int_{\lambda_1}^{\lambda_2}\frac{dI_{ph}(\lambda)}{d\lambda}} \longrightarrow \frac{Yield_{measured}}{N}(E) = \frac{Yield_{produced}}{N}(E) < QE \cdot GE >$$



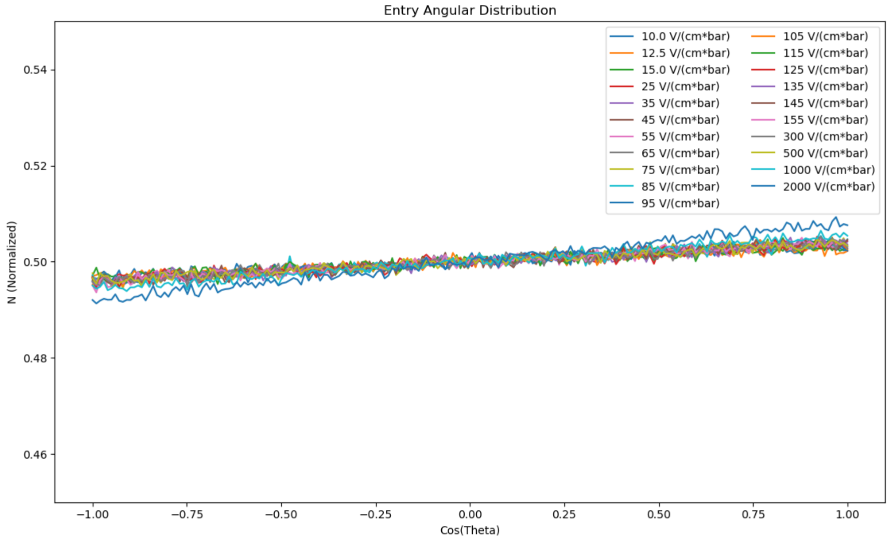


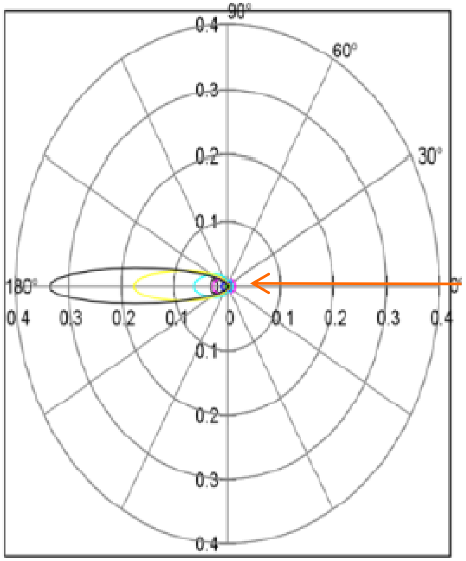


SIMULATIONS

- The angular distribution of emitted photons in the NBS is highly anisotropic at these energies

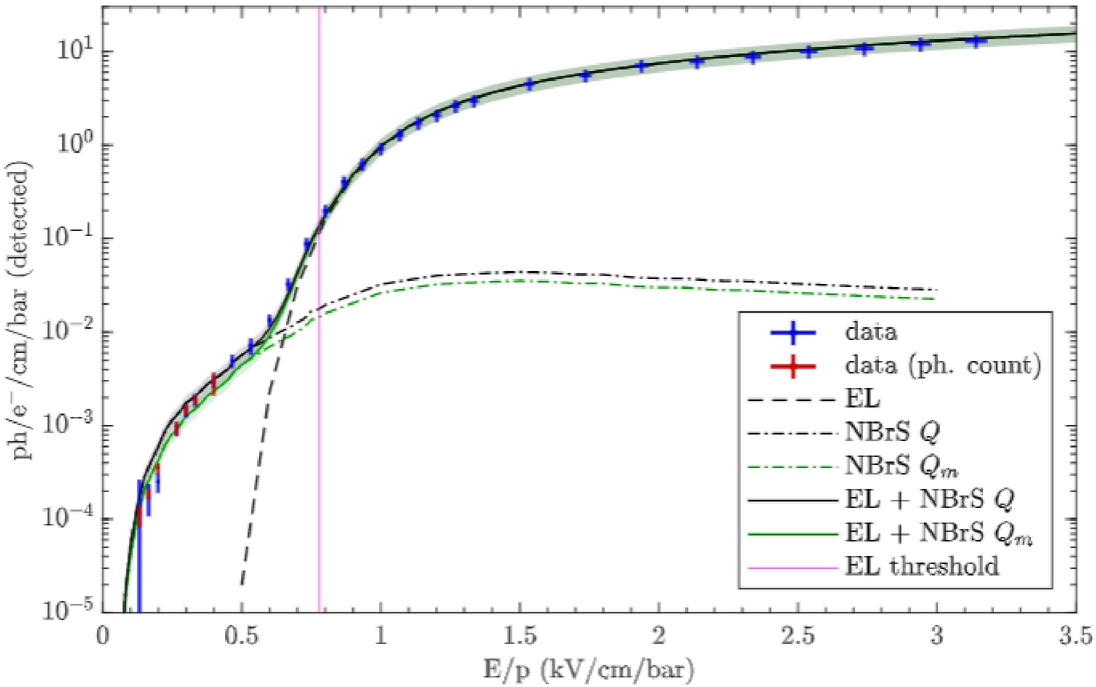
-Due to the fact that the angular distribution for electrons prior to scattering is pretty isotropic, it “isotropizes” the emission of NBS





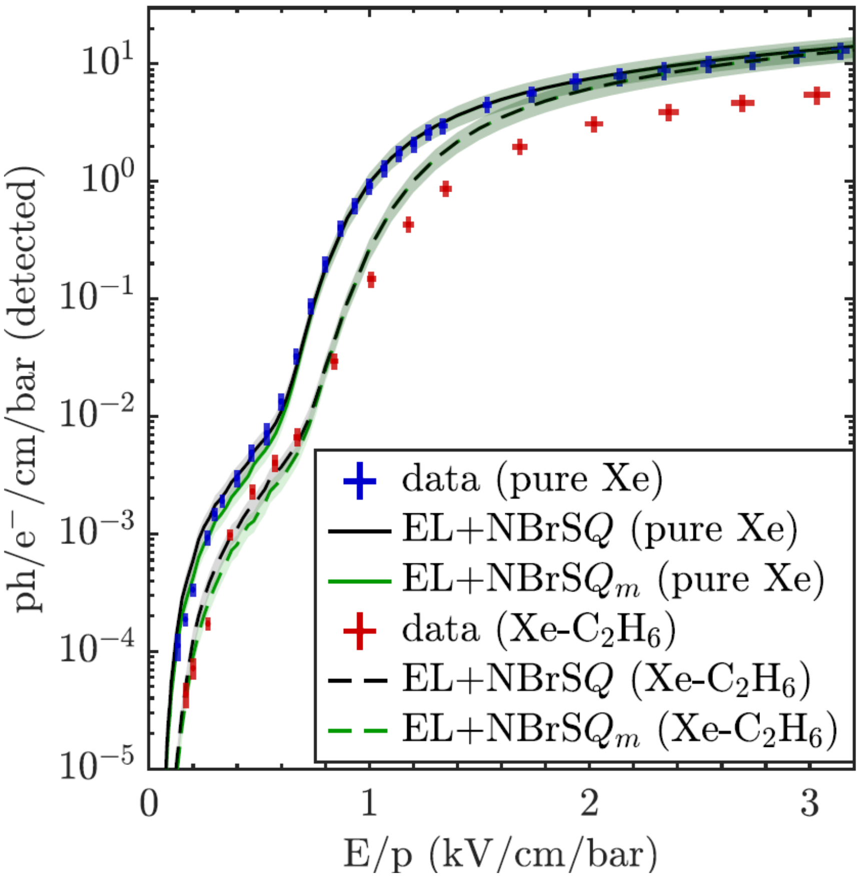
COMPARISON OF RESULTS

- Detected photons for pure Xenon. Experimental vs Simulations.



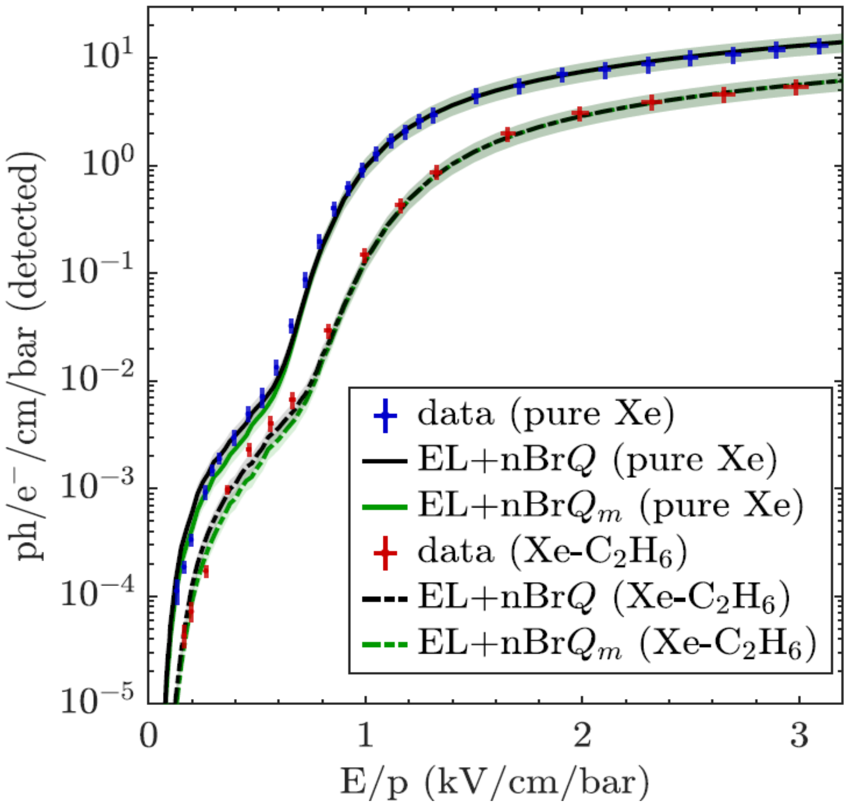
Comparison of results

- Detected photons Xenon-C2H6. Experimental vs Simulations.



Comparison of results

- Quenching rate as a global free parameter



Conclusions

-The phenomena of light emission below the EL threshold exists in Xenon

-It doesn't appear to be quenched when an additive is added

-The experimental results and simulations are in good agreement, pointing to NBS as the source of light