Measurements of the Birks-Onsager quenching parameters for the LYSO scintillator

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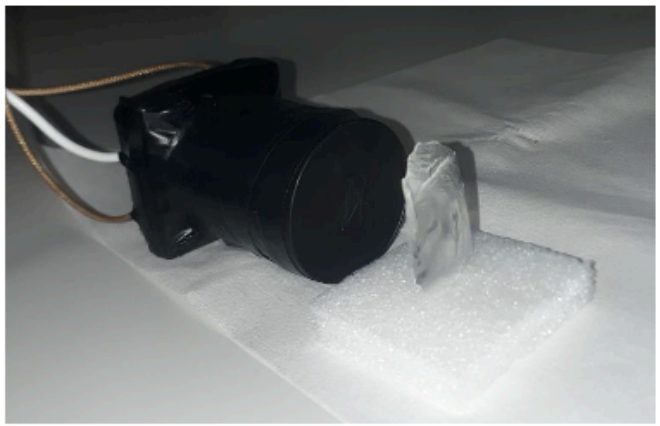
Non-proportional light response

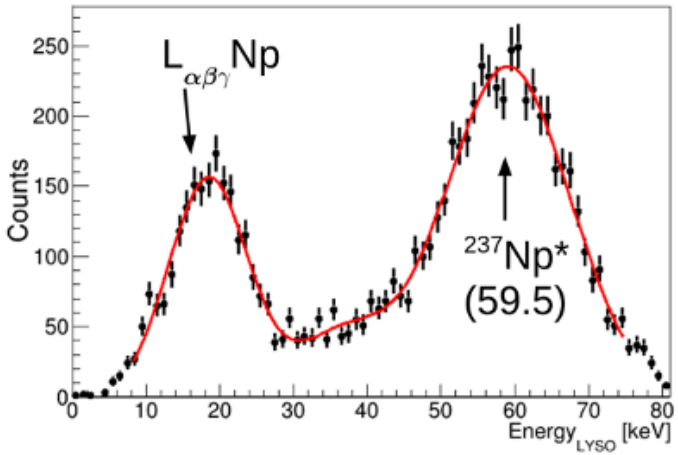
The ionization process in materials, first proposed in 1961, entails three types of carriers: excited states of single electrons, holes, and "excitons". Models proposed in the literature (Ref. [1]) suggest that quenching occurs due to excitons recombination process, which does not emit light (Auger-like). Quenching is represented by the Birks equation for high ionization density (the term on the left) and by Onsager for low density (the term on the right). The overall luminous efficiency integrates both mechanisms and is expressed as a function of four parameters.

$$L = \left[\frac{1-\eta_H}{1+k_B\left(1-\eta_H\right)\frac{dE}{dx}}\right]\left[1-\eta_{e/h}\exp\left(-k_0\frac{dE}{dx}\right)\right] \qquad (1)$$

Our measurement of LYSO Light Yield with x/γ rays

We utilize a 7.9g LYSO slice coupled to a PMT (Hamamatsu R5946) testing the scintillator non-linearity to x/γ rays from ^{241}Am (figure below) ^{133}Ba ^{176}Lu ^{22}Na ^{137}Cs and ^{60}Co radioactive sources.



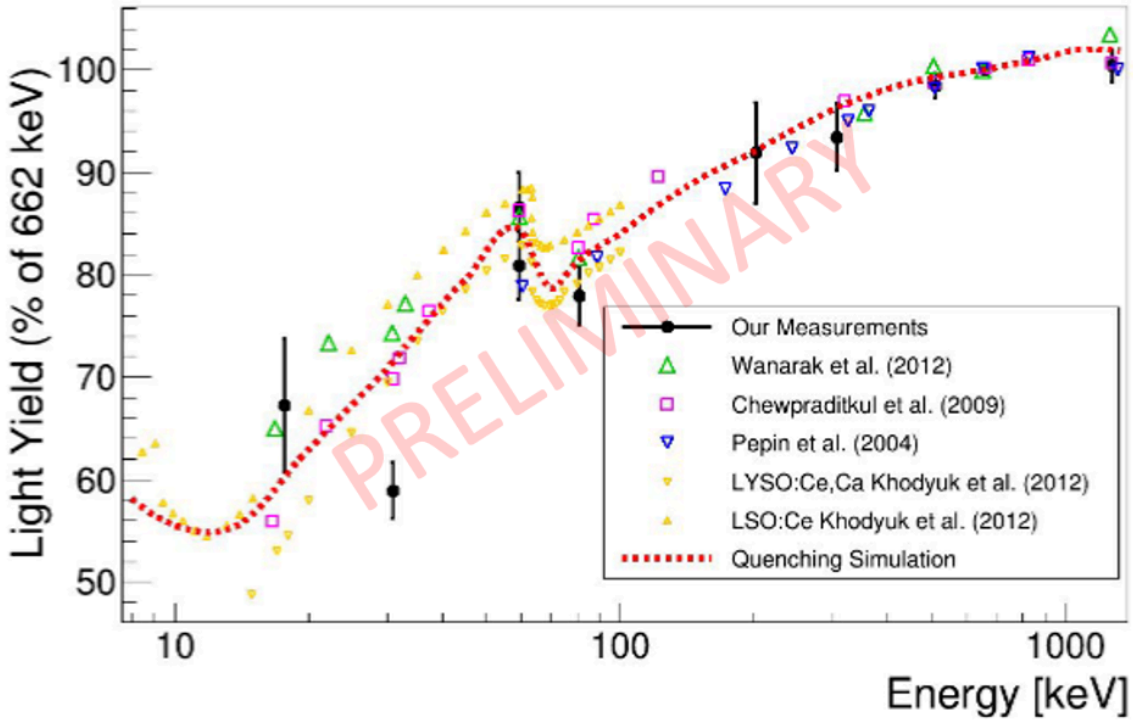


Our measurement of LYSO Light Yield with protons

We employed proton beams at the Trento Protontherapy Center to perform measurements at higher dE/dX. Our setup involved placing a 15x5x2.5 cm^3 LYSO bar in the trajectory of the proton beam, with two PMTs positioned alongside the crystal to detect light production. A plastic scintillator served as the trigger, while a tracker comprising ALTAI chips precisely measured the angle of the protons.

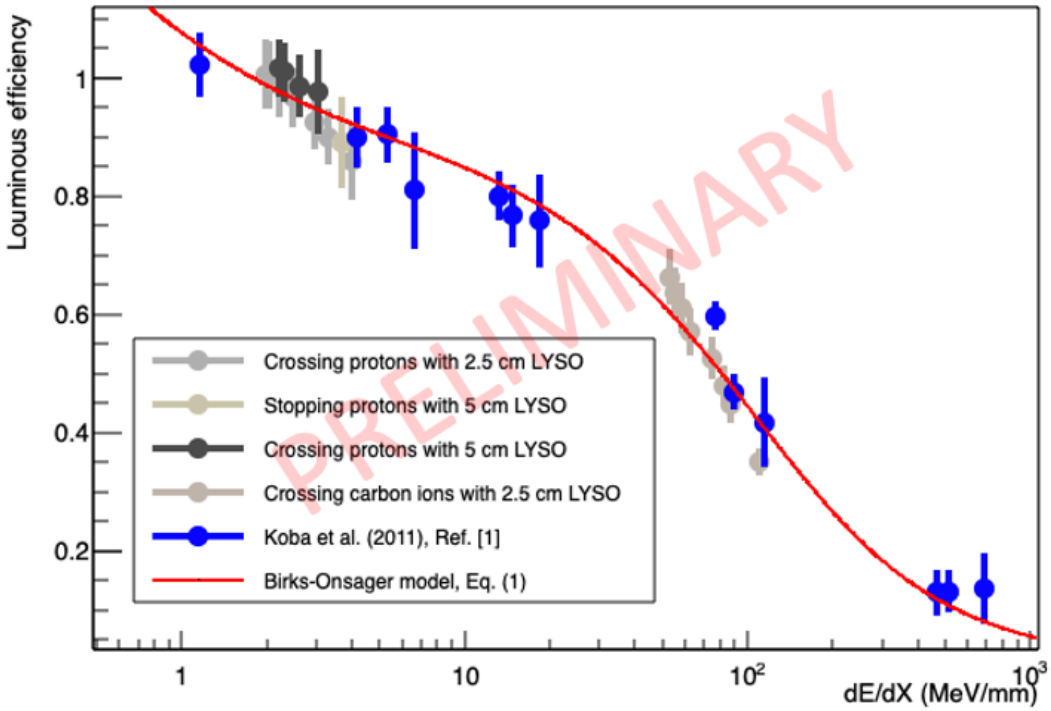
Results with photons

The light yield measured for our LYSO crystal (black points) is compared with the existing published measurements for other similar crystals. The red line is the result of our Geant4 simulation of the expected light yield using the parameters of Eq. 1.



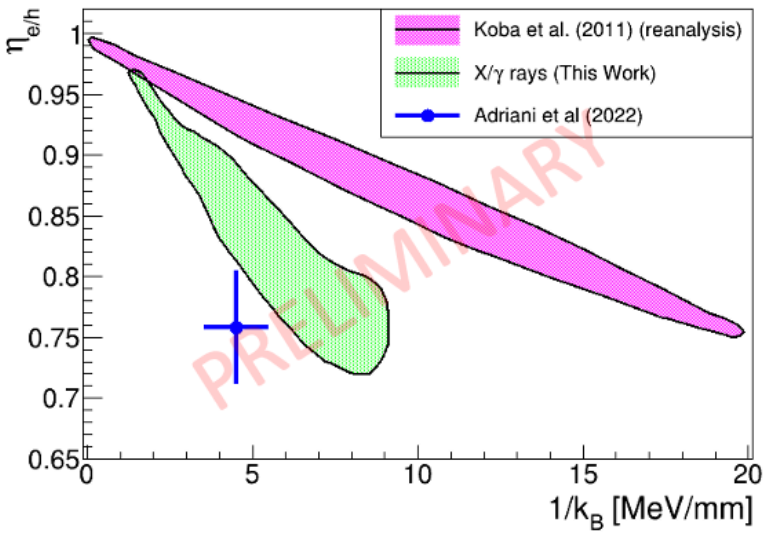
Results with protons

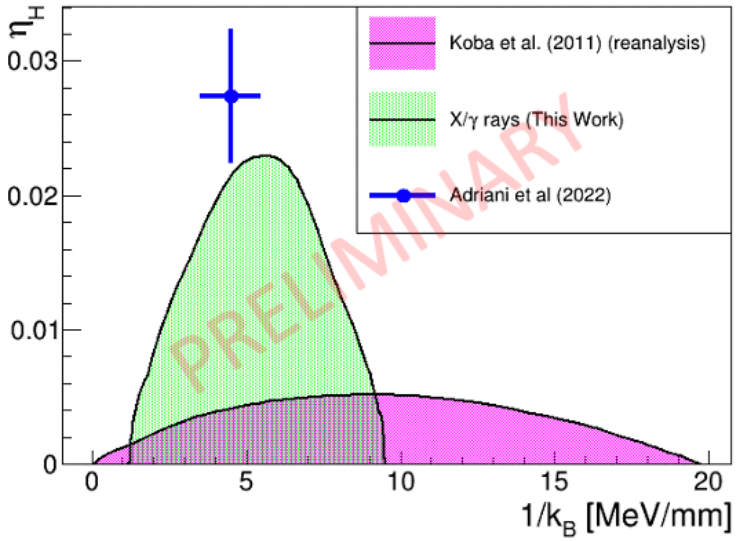
Comparison between our experimental data obtained with protons and ^{12}C along previous measurements of [2] obtained with: electrons, protons, ^{4}He, ^{12}C and ^{40}Ar.



Comparison of the different parameter estimations

The interpretation of previous measurements [1, 2] within the framework of Eq. 1 provides a not full compatibility. reveals partial compatibility. Our preliminary measurements with x/γ-rays suggest the presence of an intermediate region in parameter space. Further analysis is necessary to elucidate this issue.





Conclusions

Thanks for the attention!

References

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[1] O. Adriani, E. Berti, P. Betti, G. Bigongiari, L. Bonechi, M. Bongi, S. Bottai, P. Brogi, G. Castellini, C. Checchia *et al.*, "Light yield non-proportionality of inorganic crystals and its effect on cosmic-ray measurements," *Journal of Instrumentation*, vol. 17, no. 08, p. P08014, 2022.

[2] Y. Koba, H. Iwamoto, K. Kiyohara, T. Nagasaki, G. Wakabayashi, Y. Uozumi, and N. Matsufuji, "Scintillation efficiency of inorganic scintillators for intermediate-energy charged particles," *Progress in Nuclear Science and Technology*, vol. 1, no. 0, pp. 218–221, 2011.